UNIVERSIDADE EDUARDO MONDLANE

FACULTY OF ENGINEERING

MASTER'S THESIS

RISK AND IMPACT ANALYSIS IN MAINTENANCE PROCESS AT COCA-COLA COMPANY – CHIMOIO

A Dissertation by

DALTON JOÃO BLAUNDE

Supervised by:

Prof. Doutor João Chidamoio, Eng°

Maputo

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DECLARATION OF DOCUMENT ORIGINALITY

"I declare that this dissertation has never been submitted to obtain any degree or in any other context and is the result of my own individual work. This dissertation is presented in partial fulfillment of the requirements for the degree of Master of Science in Health, Safety and Environment, from the Universidade Eduardo Mondlane".

Submitted by:

Dalton João Blaunde

ABSTRACT

Coca-Cola company as a manufacturing company located in Mozambique have challenges to increase productivity with deliverability and flexibility, therefore the company is finding smarter ways of handling production disturbances through smart maintenance. Therefore, there is a necessity to improve risk reduction while ensuring safety and this is a fundamental requirement for the company’s profitability and sustainability; and is known that the costs of non-preventions are very high.

The main purpose to develop this project is in maintenance operations to understand how the safety tools can be used in reducing production disturbance. The focus of this study laid on application of risk analysis and safety tools to assess the rate of incident and accidents that normally occur in the scheduled and/or unplanned maintenances and to provide improvements on work conditions.

The results have shown that there’s a need to take special attention on the maintenance due to the high exposure that the results presented. The people who are responsible for the HSE management should have special attention on maintenance technicians. The constant warning and training are crucial as the results of FMECA gave concerning to the risk factor.

This project is an improvement on the HSE department specifically on the critical part of maintenance due to the level of exposure compared to other technicians on the plant. A regular assessment close to the maintenance technicians will be required to evaluate if there’s a residual risk on the operation that was overseen.

DEDICATION

This dissertation is dedicated to my Lord and Savior Jesus Christ for all things and all my family.

ACKNOWLEDGEMENTS

First, I would like to thank the UEM, UTT and TJS for the opportunity to be in this master's program and for all efforts to make it possible even more in this pandemic period. Also, a big thanks for the professors (in special professor Raed) for all knowledge shared where was possible to develop this project. And Prof. Chidamoio for all support.

Not forgetting my dear tutor Tómas Portugal for all support, day and night teaching me the practical techniques of HSE. To the Coca-Cola company – Chimoio for the opportunity of this project on the company.

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CHAPTER I: GENERAL INTRODUCTION

1. INTRODUCTION

Coca-Cola is a company dedicated to the manufacture of soft drinks and other non-alcoholic beverages, located on national road N ° 6, neighborhood Nhamadjessa, Chimoio city, Manica Province. Being an international company, it started its activities in Mozambique on May 25, 1994. Since the establishment of the factory in Chimoio, it had only one production line, which was made of glass bottles, but in January 2013, an estimated investment of US $ 20 million was made for the installation of a new soft drink production line in plastic bottles.

The company has almost the same equipment's for production. The difference is on the bottles, where one line produces on returnable glasses bottles (RGB) and other in polystyrene bottles (PET). The machines work connected with conveyors which transport bottles from one section to another, they are also connected in terms of work, i.e., they are connected in a series arrangement where when one machine stops all the line stops too. The maintenance operations are carried out by two groups, the mechanical technician and electrical technician. As the productions line works 24 hours per day, each production line has one day per week for preventive maintenance activities.

The company has four management standards which regulate the Health, Safety, Environment and quality management (see figure 1-1). Also, there's KORE as a framework of governance and management system around which the Coca-Cola system enables sustainable performance, meets customer and consumer demands, drives continuous improvement, manages risk and enhances the Company's reputation.

Figure 1-1: Coca-Cola management systems, source: Author

In Coca-Cola Company maintenance activities, contrary to normal operation (production workers), direct contact between the worker and machine cannot be reduced substantially; maintenance is an activity where workers need to be in close contact with processes. The maintenance workers are more likely than other workers to be exposed to a broad range of occupational hazard, working under time-pressure to complete the repair and get the equipment back on-line, especially when shutdowns or high-priority repairs are involved. These external pressures influence almost all maintenance workers' willingness to accept known higher risks or prevent identification or evaluation of less obvious hazards and risk. Maintenance operations typically include both disassembly and assembly, often involving complicated machinery that the company has. This can be associated with a greater risk of human error, increasing the accident risk.

In addition to the risks associated with any working environment, maintenance operations involve some specific risks. Maintenance at Coca-Cola company often involves unusual work, non-routine task in abnormal operating conditions requiring the use of a-typical, unfamiliar, equipment. This increases the risks since normal operations, routine and automation typically diminish the likelihood of human error that can lead to accidents. And specifically, under time pressure, an acute failure, high-priority repairs, risk control measures can be disabled. Maintenance involves changing tasks and working environment.

1.1. Research Objectives

The objective of this Dissertation is to identify the risks associated on maintenance activities in Coca-Cola company located in Chimoio.

- Specify the scope of the hazard, aspects and risks and their impacts;
- Identify the highest hazards for all foreseeable circumstances;
- Determine the mitigation measures to the hazardous events;

1.2. Motivation, Contribution, Significance

The purpose of this Dissertation is to make analyses on maintenance activities to find the problems that are faced on digitalized industry (industry 4.0) but putting focus on application of risk management tools to assess the rate of incident and accidents that occurred in the scheduled maintenances versus unplanned maintenances to optimize maintenance in digitalized industry for safety measurement, not only this but also the impact to the environment. By doing this, will be possible to understand, optimize and manage the causes related to high cost of breakdown and reduction of the productivity.

1.3. Research Questions

Safety on maintenance is very essential when handling production activities there is need to determine cases accompany the flaws which are detriment to high output of production and reliability. Therefore, some questions need to be investigated as:

- Question 1: How can maintenance be used to improve production?
- Question 2: How can risk management optimize the costs of industries 4.0?
- Question 3: How to reduce the risks for maintenance workers?

CHAPTER II: LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2. THEORICAL FRANEWORK

This chapter is composed with different kinds of theories of articles and books to support the findings in this research. This theorical framework looks in different points of view of hazards, risks tools and maintenance activities.

2.1. Basic concepts and definitions

2.1.1. Accident

Among the field of health and safety, there’s many confusions concerning the words accident, incident, and near miss incident. In some literature, the term incident is used to describe near misses, but since the modern approach is to term accidents (loss producing undesired event) as incidents, this confusion between accident and incident still exists.

A near miss accident is defined by American Society of Safety Engineers (ASSE) as an incident and further defines it as “an undesired event that, under slightly different circumstances, could have resulted in personal harm or property damage; any undesired loss of sources”. This definition give confusion because seems to be a combination of the definitions of an accident and a near miss incident.

Therefore, to understand what an accident can be, we need first to consider 4 fundamental statements:

1. All accidents are incidents.
2. All incidents are not accidents.
3. All injuries result from accidents
4. All accidents do not result in injury

With these statements it’s possible to separate in categories the accidents and incidents. An accident is an unexpected, unplanned event in a sequence of events, that occurs through a combination of causes; it results in physical harm (injury or disease) to an individual, damage to property, a near-miss, a loss, or any combination of these effects (Ridley & Channing, Safety at work, 2008). This given definition requires recognition of a wider range of accidents than those resulting in injury.

2.1.2. Near miss incident

According to (McKinnon, 2012), a near miss incident does not result in any injury, damage, or business interruption, but has the potential to do so under slightly different circumstances.

In some accidents, there also can be near miss incidents involved.

2.1.3. Hazard

The Management of Health and Safety at Work Regulation of 1999 defines a hazard as something with the potential to cause harm (this can include substances or machines, methods of work and other aspects of work organization).

2.1.4. Injury

An injury is defined as the bodily hurt sustained as a result of an accidental contact, this include any illness or disease arising out of normal employment (McKinnon, 2012).

The injury is a direct result of contact with a substance or source of energy greater than the resistance of the body.

2.1.5. Risk

The risk from a substance is the likelihood that it will cause harm in the actual circumstances of use. This will depend on: the hazard presented by the substance; how it is used; how it is controlled; how is exposed, for how much, for how long. (Ridley & Channing, Safety at work, 2008).

2.1.6. Failure

According to (Narayan, 2012), failure is the inability of a process plant, system, or equipment to function as desired. Thus, when there is a failure, we cannot produce widgets or serve customers. Similarly, when traffic jams take place, there is a system failure. In other words, performance will drop to level below predetermined acceptance standards. Every process is a susceptible to failure.

In minor failure occur very frequently however, there is a chance that some of them may escalate to a higher level. Therefore, if there’s a high frequency of small break of a machine, there is a distinct possibility that one of them will escalate into a major break. Similarly, in an installation that experiences many minor injuries, one can expect a lost-time injury sooner or later.

2.1.7. Exposure

To understand well what exposure can mean, let us bring an event that is launch with a frequency.

If someone must cross a road frequently, your exposure to a road accident is higher than if you did not have to cross the road often. The traffic density also affects the exposure, rising as the traffic increases. The demand rate or the number of times we call on something to work, is the industrial equivalent of exposure.

2.1.8. Risk exposure

Higher exposure as maintenance is carried out to some extend in all sectors and workplaces, maintenance workers are more likely than other workers to a broad range of occupational hazards. Data from the Spanish working conditions survey indicate a higher exposure of maintenance workers to noise, vibration and different kinds of radiation when compared to the rest of the working population. Maintenance workers are also more exposed to heat in summer (44% compared to 19% among other occupations), cold in winter (44% compared to 17%) and a humid atmosphere (25% compared to 13%), and are more exposed to dangerous substances, vapors and fumes ,(Blaise, 2017).

Maintenance workers are more likely than other employees exposed to a wide variety of risks, which may lead to various occupational diseases. There are:

- **Physical risks:** noise, vibration, excessive heat and cold, radiation, and high physical workload, ergonomics-related risks,
- **Chemical risks**: Asbestos, glass fiber, vapors, fumes, dust, solvents,
- Biological risks: bacteria,
- **Psychosocial risks:** time pressure, shift work, stress, often related to poor work organization.

In addition to the risks associated with any working environment, maintenance operations involve some specific risks.

Maintenance often involves unusual work, non-routine task in abnormal operating conditions requiring the use of a-typical, unfamiliar, equipment. This increases the risks since normal operations, routine and automation typically diminish the likelihood of human error that can lead to accidents. And specifically, under time pressure, an acute failure, high-priority repairs, risk control measures can be disabled. Maintenance involves changing tasks and working environment.

2.2. Maintenance

According to the BS EN 13306:10, Maintenance is a combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it can perform the required function. This can involve unplanned and planned actions so that in a given period is possible to retain in a good condition.

To achieve a good level of production, reliability, availability, and safety was due to the industrialization and a very high competitiveness among the producers.

2.2.1. Types of Maintenance

(Godians & Ramachandra, 2018) identify six general types of maintenance philosophies, namely: reactive, preventive, predictive, Pro-active, Risk based and smart maintenance.

The reactive maintenance system is carried out when the system of machine or equipment breakdown before maintenance personal carries out maintenance work, it is also known as corrective maintenance. It can be referred as maintenance which is carried out following detection of an abnormal and aim at restoring normal operating conditions.

The preventive maintenance system is mostly done to disallow breakdown to occur when the machine or equipment are still operating in good conditions. This maintenance is also perceived as a periodic maintenance of system to prevent breakdowns.

The predictive maintenance system can be described as the one that involves maintenance operations only as the state required application of modern measurement and signaling processing methods to correctly checkmate equipment conditions during functional state.

Proactive maintenance system is a strategy in which machine or equipment breakdown are avoided through systemic methods as it is in TPM whereby acts to improve overall equipment operation.

Risk-based maintenance is used to reduce overall risk which can result in unanticipated failures of machines or equipment’s. The focus is to prioritize maintenance effort based on high and medium risk, while the areas which are low risk, the efforts required are reduced to balance the cost of maintenance program in a controlled way. It will greatly reduce the probability of an unexpected failures due to quantifiable priority value of risk used to arrange inspection procedures in maintenance activity.

The smart maintenance system: this type of maintenance is due to the leading transformation in the direction of industries 4.0 revolution more software intelligence is embedded in production and maintenance systems. An intelligence network surrounding machine systems with electronics and algorithms have greater effect on performance of machines. Thus, making normal regular machines into self-operating and self-learning ability which subsequently improves performance of machines and maintenance management.

2.2.2. Maintenance concepts

It comprises kinds of maintenance activities which act as complied sets of details of task to see the system breakdown is minimized or eliminated during production activities, for instance Total Productive Maintenance (TPM), Reliability Centred Maintenance (RCM) etc. are set that provide services and upkeep of proactive actions. Therefore, the ideology of maintenance concept is based on safety-based maintenance concept which is known as a system, is a central place activity occurs, in which those activities are ready to adjust its plans and processes daily according to emerged circumstances and it has to be able to make preparations to achieve maximal involvement in the performance of maintenance task in short period of time (Godians & Ramachandra, 2018).

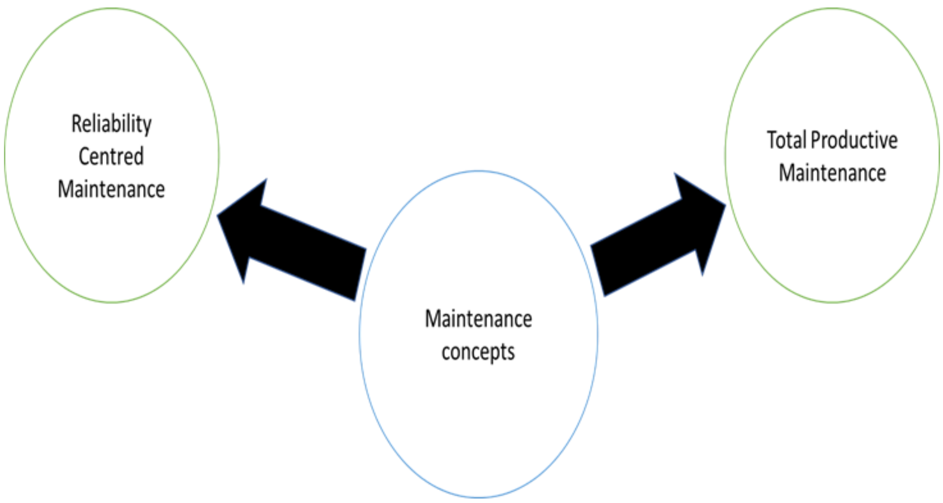

Figure 2-1: Maintenance concepts

2.2.3. Reliability Centred Maintenance (RCM)

RCM is a method which is used to identify what must be done to confirm that any equipment or machines remains to operate and function in the present operational condition and relying on TPM basis but not in run to failure basis (Godians & Ramachandra, 2018).

2.2.4. Total Productive Maintenance (TPM)

The main goal of TPM is to take full advantage of overall plant and effectiveness of equipment to accomplish best life cycles of production machines. The targets of TPM are to improve production, Quality, Cost saving, Delivery and safety which results in reduction of breakdown, quality complaints, safety and environmental issues, cost of unplanned maintenance, improved output with competitive advantage (Godians & Ramachandra, 2018).

The primary purpose of TPM is to confirm that all machines should operate at full efficiency and should always be available. TPM demands autonomous maintenance where operators are required to conduct basic maintenance activity before and after the operation of machines, these includes, lubrification, checking sensors, minor calibration and do basic cleaning at the end of the shift.

2.2.5. Maintenance management

all activities of the management that determine the maintenance objectives, strategies and responsibilities, and implementation of them by such means as maintenance planning, maintenance control, and the improvement of maintenance activities and economics.

2.2.6. Objectives of the maintenance

Equipment's are an important resource which is constantly used for adding value to products. So, it must be kept at the best operating condition. Otherwise, there will be excessive downtime and also interruption of production if it is used in a mass production line. Poor working of equipment will lead to quality related problems. Hence, it is an absolute necessity to maintain the equipment in good operating conditions with economical cost. Therefore, we need an integrated approach to minimize the cost of maintenance. In certain cases, the equipment will be obsolete over a period of time. If a firm wants to be in the same business competitively, it has to take decision on whether to replace the equipment or to retain the old equipment by taking the cost of maintenance and operation into account.

2.2.7. Imperfect Maintenance

According on previous description, maintenance can be classified by two major categories: Corrective maintenance and preventive. Corrective maintenance (CM) is the maintenance that occurs when the system fails. This action is performed at unpredictable time points because an item's failure time is not known and is typically carried out in three steps which are: Diagnosis of the problem; Repair and/or replacement of faulty component; and verification of the repair action. Preventive maintenance (PM) is the maintenance that occurs when the system is operating.

Maintenance can also be classified according to the degree to which the operating condition of an item is restored by maintenance in the following way:

Perfect repair/maintenance: maintenance actions which restore a system operating condition to 'as good as new'. That is, upon a perfect maintenance, a system has the same lifetime distribution and failure rate function as a new one.

Minimal repair/maintenance: maintenance actions which restore a system to the same failure rate it had when it failed. The system operating state after the minimal repair is often called 'as bad as old' in the literature.

Imperfect repair/maintenance: maintenance action which make a system not 'as good as new' but younger. Usually, it is assumed that imperfect maintenance restores the system operating state to somewhere between 'as good as new' and 'as bad as old'. Imperfect repair is a general repair which can include two extreme cases: minimal and perfect repair.

Worse repair or worse maintenance: maintenance actions which undeliberately make the system failure rate or actual age increase but the system does not break down. Thus, upon worse repair a system's operating condition becomes worse than that prior to its failure.

2.2.8. Dependence

Maintenance of a multicomponent system differs from that of a single-unit system because there exists dependence in multicomponent systems. Economic dependence is common in most continuous operating systems. Example of such systems include aircraft, ship, power plants, telecommunication systems, chemical processing facilities, and mass production lines. For this type of system, the cost of system unavailability may be much higher than component maintenance costs. Therefore, there is often great potential cost saving by implementing an opportunistic maintenance policy according to (Huang and Okagbaa 1996, as cited in Wang & Pham, 2006).

According to (Wang & Pham, 2006), the joint maintenance of two or more subsystems tends to spend less cost and less time (economic dependency), and the failures of different subsystems in multicomponent system may not be independent (failure dependency). Thus, each subsystem may not be considered as a single-unit system individually and to apply the existing optimum maintenance models of a single-unit system to each of such subsystems may not lead to a global optimal maintenance policy for the system.

2.3. Engineering Reliability

The reliability of engineering systems has become an important issue during their design because of the increasing dependence of our daily lives and schedules on the satisfactory functioning of these systems (Dhillon, Maintenability, Maintenance, and Relisbility for Engineers, 2006).

The required reliability of engineering systems is specified in the design specification, and during the design phase every effort is made to fulfill this requirement effectively. Some of the factors that play a key role in increasing the importance of reliability in designed systems are the increasing number of reliability and quality, related lawsuits, competition, public pressures, high acquisition cost, past well-publicized system failures, and complex and sophisticated systems.

2.3.1. Reliability configuration

An engineering system can form various configurations in performing reliability analysis. Here we are going to describe only two configurations, series and parallels.

Series configuration

The series configuration is the simplest reliability configuration/network shown in figure 2-2. The diagram denotes an n unit series system, and each block in the diagram represents a unit. For the successful operation of the series system, all its n units must operate normally. In the other words, if any one of the n units fails, the series system/configuration fails.

The series configuration reliability is expressed by:

$$R_{sc} = P(E_1 E_2 E_{3\dots} E_n) \qquad \text{Equation 1}$$

Where:

R_{sc} is the series configuration reliability

E_j is the successful operation of unit j, for *j* = 1, 2, 3, …, *n*.

$P(E_1 E_2 E_3 \ldots E_n)$ is the probability of occurrence of events $E_1, E_2, E_3, \cdots E_n$.

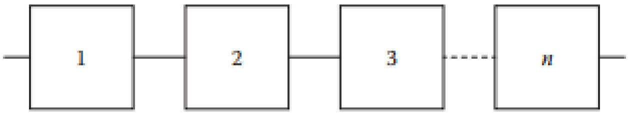

Figure 2-2: Series configuration

Parallel configuration

In the case of parallel configuration, the system is made up of *n* simultaneously operating units/items, and for the successful operation of the system, at least one of these units/items must operate normally. The *n* unit parallel system block diagram is shown in figure 2-3, and each block in the diagram represents a unit.

The probability of failure, shown in figure 2-3, is expressed by:

$$F_{ps} = P(\bar{E}_1 \bar{E}_2 \bar{E}_3 \cdots \bar{E}_n) \qquad \text{Equation 2}$$

Where:

$\bar{E}_j$ is the failure of unit *j* = 1, 2, 3, …, *n*.

$P(\bar{E}_1 \bar{E}_2 \bar{E}_3 \cdots \bar{E}_n)$ is the occurrence probability of events $\bar{E}_1 \bar{E}_2 \bar{E}_3 \cdots and\ \bar{E}_n$

F_{ps} is the failure probability of the parallel system

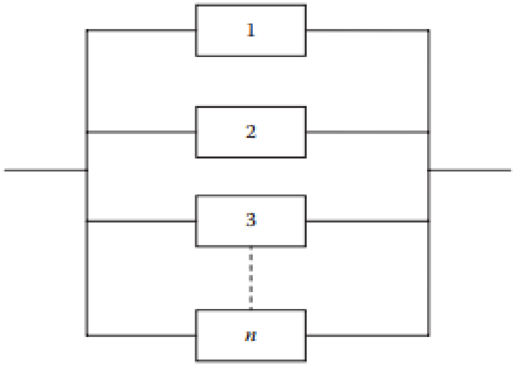

Figure 2-3: Parallel configuration

2.3.2. Bathtub hazard rate curve

The bathtub hazard rate curve is usually used for describing the failure rate of engineering systems/equipment. The curve is called the bathtub hazard rate curve because it resembles the shape of bathtub (Dhillon, Engineering Systems Reliability, Safety, and Maintenance: an integrated approach, 2017). This is a well-known concept used to represent failure behavior of various engineering items because the failure rate of such items is a function of time.

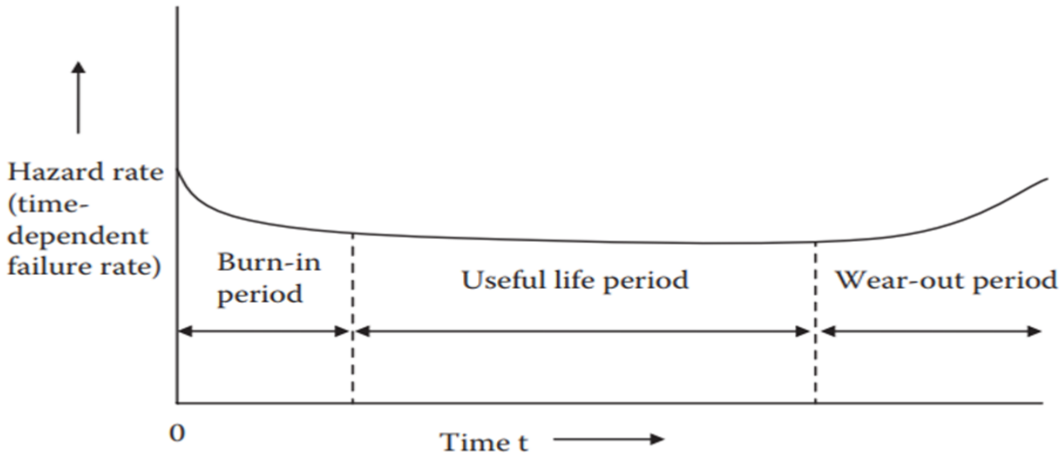

Figure 2-4: Bathtub hazard rate curve (Dhillon, 2017).

As shown in figure above, the curve is divided into three sections: burn-in period, useful life period, and wear-out period.

During the burn-in period, the system/item hazard rate decrease with time, and some of the reasons for the occurrence of failures during this time period are inadequate debugging, poor manufacturing methods and processes, poor quality control, human error, and substandard materials and workmanship. Three other terms used are: debugging region, infant mortality region, and break-in region.

During the useful life period, the hazard rate remains constant. Some of the reasons for the occurrence of failures in this region are as follows:

- Higher random stress than expected
- Low safety factors
- Undetectable defects
- Abuse
- Natural failure
- Human errors

Finally, during the wear-out period, the hazard rate increases with time t. some of the reasons for the occurrence of failures in this region are wear from aging, wrong overhaul practices, wear due to friction, corrosion, and creep; short designed-in life of the item/system under consideration; and poor maintenance practices.

2.3.3. Mechanical and Human reliability

Usually the exponentially distribution when dealing with failure rate is used to evaluate the reliability of electronic components, but for mechanical parts this kind of failure rate cannot be applied in fulness.

General mechanical failure causes and modes

In various literatures studies we can find people that describe the causes of mechanical failures and have identified them as follows:

- Poor or defective design
- Manufacturing defect
- Incorrect application
- Wrong installation
- Wear-out
- Failure of other parts or components

- Gradual deterioration in performance

These are not all mechanical failures; many different types of failure modes are associated with mechanical parts or items. They are fatigue failure, creep or rupture failure, bending failure, metallurgical failure, instability failure, shear loading failure, metal flaw failure, compressive failure, bearing failure, stress concentration failure, ultimate tensile-strength failure, and tensile-yield-strength failure.

Fatigue failure occurs because of repeated loading or unloading (or partial unloading) of an item or part. Its occurrence can be prevented by selecting appropriate materials for a specific application. For example, under cycle loading, steel outlasts aluminum. In the case of creep or rupture failure, material stretches (i.e., creeps) when the load is maintained on a continuous basis, and normally it ultimately terminates in a rupture. Also, creep accelerates with elevated temperatures.

Bending failure occurs when one outer surface is in compression and the other outer surface is in tension. An example of the bending failure is the tensile rupture of the outer material. Metallurgical failure is also known as a material failure. This type of failure is the result of extreme oxidation or operation in a corrosive environment. The occurrence of metallurgical failures is accelerated by environmental conditions such as heat, erosion, nuclear radiation, and corrosive media.

The instability failure is confined to structural members such as beams and columns those manufactured using thin material where the loading is normally in compression. However, this type of failure may also occur because of torsion or by combined loading (i.e., compression and bending). The shear loading failure occurs when shear stress becomes greater than the strength of the material when applying high shear or torsion loads.

Material flaw failure occurs because of factors such as weld defects, poor quality assurance, small cracks and flaws, and fatigue cracks. Compressive failure causes permanent deformation, rupturing, or cracking and is like tensile failures except under compressive loads.

Bearing failure usually occurs because of a cylindrical surface bearing on either a flat or a concave surface like roller bearings in a race and is similar in nature to compressive failure. The stress concentration failure occurs under the conditions of uneven stress flow through a mechanical design.

Ultimate tensile-strength failure occurs when the ultimate tensile strength is less than the applied stress and leads to a complete failure of the structure at a cross-sectional point. Tensile-yield-strength failure occurs under tension and, more specifically, when the applied stress is greater than the material yield strength.

Human error

Operator errors are the result of operator mistakes, and the causes of their occurrence include poor environment, complex tasks, lack of proper procedures, operator carelessness, and poor personnel selection and training. Maintenance errors occur in field environments because of oversights by maintenance personnel. Some examples of maintenance errors are repairing a failed item incorrectly, calibrating equipment incorrectly, and applying the wrong grease at appropriate points on the equipment.

Assembly errors are the result of human mistakes during product assembly. Some of the causes of assembly errors are poor illumination, poor blueprints and other related material, poorly designed work layout, and poor communication of related information. Installation errors occur for various reasons including failure to install equipment or items per the manufacturer’s specification and using the incorrect installation instructions or blueprints.

Design errors are the result of inadequate design. Some of the causes of their occurrence are failure to ensure the effectiveness of person–machine interactions, failure to implement human needs in the design, and assigning inappropriate functions to humans. Inspection errors are the result of less than 100% accuracy of inspection personnel. One typical example of inspection errors is accepting and rejecting out-of-tolerance and in-tolerance components and items, respectively. Handling errors occur because of improper transportation or storage facilities.

There are many causes of human errors. Some of the common ones are poor training or skills of personnel, inadequate work tools, poor motivation of personnel, poorly written product and equipment operating and maintenance procedures, complex tasks, poor work layout, poor equipment and product design, and poor job environment.

2.3.4. Performance and human error

To start, it is important to understand how people act, what influences their reactions, and what causes stresses on them. The result is to better design technological systems so that humans can use them without abusing them. People make mistakes as a result of a combination of causes.

Human performance is determined by certain factors that influence how people act. These factors are called performance-shaping factors (PSFs). PSFs are usually a complex confluence of items that affect the operator in a system and are divided into external PSFs, internal PSFs, and stressor PSFs. PSFs can greatly affect how safely a system is operated (Bahr, 2015).

External PSFs are made up of all the conditions that an individual encounters-including the entire work environment, especially the equipment design and the written procedures or oral instructions. Three general conditions are included in external PSFs: situational conditions (things that influence the individual that are plant wide or company, such as plant shift schedules and holidays), task and equipment characteristics (factors that are related only to a specific task or piece of equipment), and job and task instructions (factors that influence how an operator is taught to the task).

Internal PSFs are the factors related to the individual's previous training or experience in performing the task. Other PSFs are the individual's state of current practice or skill, personality and motivation, emotional state at the time of performing the task, and physical condition.

Stressor PSFs are much more difficult to understand and therefore are usually ignored. Unfortunately, these PSFs do influence how people can react in a hazardous situation. A stressor is stress (which can be either positive or negative in terms of performance of the task) that is applied to the individual during the task. Psychological and physiological stressors are the two major grouping of stressors.

Some of the psychological stressors that directly affect mental stress are suddenness of onset; duration of stress; task speed; task load; high-jeopardy risk; threat of failure; boring, repetitive, or meaningless work; long, uneventful vigilance periods; and distractions.

Some of the physical stressors that influence physical stress are duration of the stress, fatigue, pain or discomfort, hunger or thirst, temperature extremes, atmospheric pressure extremes, oxygen insufficiency, vibration, and disruption of circadian rhythm.

With all this regarding to human error, we can understand that human error, if not the cause, is a significant contributor to many accidents. Better understanding how people act and react to the PSDs in their environment allows us to better design systems to be tolerant or robust to human errors.

Table 2-1 shows the Human Error Probabilities (HEP) studied by Swain and Guttman, there use the table giving a generic human error. The data can change according to plant conditions.

At the End of *x* min	Primary Operator	Shift Supervisor	Joint HEP
Situation without Second Operator			
5	0.05	—	0.05
15	0.01	0.5	0.005
30	0.005	0.25	0.001
60	No change	No change	No change
Situation with Second Operator			
5	0.002	—	0.002
15	0.001	0.5	0.0005
30	0.0005	0.25	0.0001
60	No change	No change	No change

Table 2-1: Human error probability (Bahr, 2015).

The human reliability probability is also given by the following formula:

$$\textbf{Human reliability probability} = 1 - \text{HEP} \qquad \text{Equation 3}$$

2.4. Risk in maintenance operations

Maintenance is associated with a range of management processes, such safety management, environment management and quality management. When it comes to managing safety and environmental impacts in industry, the role of successful and effective maintenance is important because of the very high demands and expectations for retaining a system's inherent safety. Further, reliability is also important for environmental safety as failures and accidents in high-risk industries. From a task-based perspective, industrial maintenance poses several risks for the maintenance worker (Wijeratne, Perera, & De Silva, 2012).

In the maintenance operations, accidents and incidents occur frequently therefore it is essential to be able to handle the hazards and implement the appropriate preventive measures. Thus, it becomes very essential for industries to create an effective risk assessment technique that reduces risk which comprises both hazard identification and probability of consequences of identified risk.

According to (Lind 2009 cited in Wijeratne, Perera, & De Silva, 2012) the risk involved in maintenance activities can be separated into three main categories shown on the table below:

Table 2-2: Risks in maintenance operations, Source: Author

Organizational risk factors	Local workplace factors	Unsafe factors
• Pressure of time • Aging of skilled operators • Frequent changing of working sites • Large variance in maintenance activities	• Unsafe acts – Slips, trips and falls • Missing safety guards • Missing safety points • Hot or cold environments • Falling objects • Lack of air (ventilation)	• Not using personal protective equipment's • Ergonomical risks – working in wrong postures, carrying excessive weights • Poor safety adaptation and attitudes

2.4.1. Typical hazards of machinery

An essential element in the safe use of machinery is the identification of hazards so that action can be taken to remove them before harm or injury are caused. This applies equally to new machines where the onus is on the designer and manufacturer as well as to existing machinery where the responsibility lies with engineer and manager of the employer (Ridley & Pearce, Safety With Machinery, 2006).

Agents of hazards

Machinery hazards arise from a discrete number of sources – movement, energy, sharp edges, electricity, materials, physical agents and radiations.

Each of these is considered in appendix C.

2.5. Safety in maintenance operations

According to (Dhillon, Maintenability, Maintenance, and Relisbility for Engineers, 2006), safety in maintenance is becoming an important issue, as accidents occurring during maintenance work or concerning maintenance are increasing significantly. Some of the main reasons for safety problems in maintenance are poor safety standards and tools, poor equipment design, poor training of maintenance personnel, insufficient time to perform required maintenance tasks, poorly written maintenance instructions and procedures, poor management, poor work environments, and inadequate work tools.

One of the important ways to improve maintenance safety is to reduce the requirement for maintenance as much as possible in products and systems during their design phase. When the need for maintenance cannot be avoided, designers should follow guidelines such as those listed below for improving safety in maintenance.

2.5.1. Product Hazard Classifications

There are many product-related hazards. They may be grouped under six classifications.

Classification I: electrical hazards have main elements: electrocution hazard and shock hazard. The major electrical hazard to system/product stems from electrical faults, frequently referred to as short circuits.

Classification II: Energy hazards may be divided into two categories: kinetic energy hazards and potential energy hazards. The kinetic energy-related hazard pertains to items that have energy due to their motion. Two examples of these items are flywheels and fan blades. Any object that interferes with such items' motion can experience extensive damage. The potential energy-related hazards pertain to items that store energy. Three examples of these items are electronic capacitors, spring, and counterbalancing weights.

During equipment servicing, such hazards are very important because stored energy, when released, can suddenly result in serious injury.

Classification III: Kinematic hazards pertain to situations where parts/items come together while moving and result in pinching, cutting, or crushing and object/item caught between them.

Classification IV: Environmental hazards may be divided into two categories: external hazards and internal hazards. External hazards are the hazards posed by the system product during its life span and include items such as disposal hazards, maintenance-related hazards, and service-life operation hazards. The internal hazards are concerned with the change in the surrounding environment that result in an internally damaged product/system/item. A careful consideration to factors such as extremes of temperatures, vibrations, electromagnetic radiation, atmospheric contaminants, and ambient noise level during the design phase can be very helpful for eliminating or minimizing the internal hazards.

Classification V: Misuse-and-abuse hazards are concerned with the usage of product/system by humans. Misuse of a product/system can cause serious injuries, and its abuse can lead to injuries or hazardous situations. Two examples of the causes for product/system abuse are poor operating practices and lack of proper maintenance.

Classification VI: Human factors hazards are concerned with poor design in regard to humans, that is, to their length of reach, physical strength, weight, height, visual angle, visual acuity, intelligence, and computational ability, etc.

2.6. Reliability prediction theory

Reliability prediction (modeling) is the process of calculating the anticipated system RAMS from assumed component failure rates. It provides a quantitative measure of how close a proposed design comes to meeting the design objectives and allows comparations to be made between different design proposals (Smith, 2011).

- ✓ Is important to note that reliability prediction is an imprecise calculation, but is nevertheless a valuable exercise for the following reasons:
- ✓ It provides an early indication of a system's potential to meet the design reliability requirements.
- ✓ It enables an assessment of life-cycle costs to be carried out.
- ✓ It enables one to establish which components, or areas, in a design contribute to the major portion of the unreliability.
- ✓ It enables trade-offs to be made as, for example, between reliability, maintainability, and proof-test intervals in achieving a given availability.
- ✓ Its use is increasingly called for in invitations to tender, contracts and in safety-integrity standards.

2.7. Accident Causation Models

Accident causation can be intended as the starting reasons or factors for an accident. Those factors are the key to eliminate hazards and accidents to improve the safety in the workplace. There are many theories concerning accident causation, here we are going to describe some of them.

2.7.1. Human factors accident theory

According to (Dhillon, 2017) the basis for the human factors accident causation theory is the assumption that accidents occur due to a chain of events directly or indirectly due to human error. The theory consists of three main factors that lead to the occurrence of human error.

The factor overload is concerned with the imbalance between a person's capacity at any point in time and the amount of load he is carrying in a given state. The capacity of a person is the product of many factors including natural ability, stress, state of mind, degree of training, physical condition, and fatigue. The load carried by a person is composed of tasks for which he has responsibility along with additional burdens resulting from the situational problems which can be the level of risk, unclear instruction, etc.; internal factors as personal problems, worry, etc.; and environmental factors as distractions, noise, etc.

The factor inappropriate response/incompatibility is another human error causal factor, and three examples of inappropriate response by a person are as follows:

- ✓ A person disregarded the stated safety procedures.
- ✓ A person removed a safeguard from equipment for improving output.
- ✓ A person detected a hazardous condition but took no necessary corrective action.

Human factors can include loss of sleep, inattention or a lack of knowledge about safety measures.

2.7.2. Domino accident causation model

This theory explains accidents using the analogy of dominos falling over one another and creating a chain of events. While this theory is not the most advanced or complex theory, it is especially noteworthy as one of the first scientific theories used to explain accidents (DeCamp & Herskovitz, 2019).

When dominos fall over, each tips the next enough to push it over and continue the process until all the connected dominos have fallen. However, if just a single domino is removed, the entire process ceases.

The domino accident causation theory is encapsulated in ten statements by H.W. Heinrich, called the axioms of industrial safety. And there are five factors in the sequence of events leading up to an accident: Social environment and Ancestry, Faults of a person, Unsafe act or condition, Accident, Injury.

- ❖ Statement 1: Supervisors play a key role in industrial accident prevention.
- ❖ Statement 2: An unsafe condition or unsafe act by a person does not always immediately lead to an accident/injury.
- ❖ Statement 3: Most accidents are the result of unsafe acts of people.
- ❖ Statement 4: An accident can occur only when a person commits an unsafe act and/or these is a physical – or mechanical related hazard.
- ❖ Statement 5: Management should assume full safety responsibility with vigor because it is in the best position for achieving results effectively.
- ❖ Statement 6: There are two types of costs of accident: direct and indirect.
- ❖ Statement 7: the occurrence of injuries results from a completed sequence of several factors; the last or final one of which is the accident itself.
- ❖ Statement 8: The reason why humans commit unsafe acts can be useful in selecting appropriate corrective measures.
- ❖ Statement 9: The severity of an injury is largely fortuitous, and the specific accident that caused it is generally preventable.
- ❖ Statement 10: The most helpful accident-prevention methods are analogous to the productivity and quality approaches.

2.7.3. Swiss cheese model

The Swiss cheese model is used in risk analysis to understand the cause of risks or accidents in simplified way which may be root for system failures primarily to operators and machine. The model consists of several layers or barriers which are unplanned weaknesses or holes. These holes are inconsistent therefore holes open and closes randomly and when these holes align then the potential risks lead to accidents. And the holes in the barriers occurs for two different reasons:

- ✓ Active failures – these are unsafe acts that are performed by operators who are directly handling the machines or equipment's which are caused due to not following standard procedures and committing mistakes.
- ✓ Latent conditions – These are the lapses in the system itself caused by strategic decisions made by the designers, procedure makers and top-level management can be inadequate experience, lack of equipment's, failures in safety alarms or indicators and industrial structural deficiencies (which can involve lack of ventilation, exhaust, sewage and drain system).

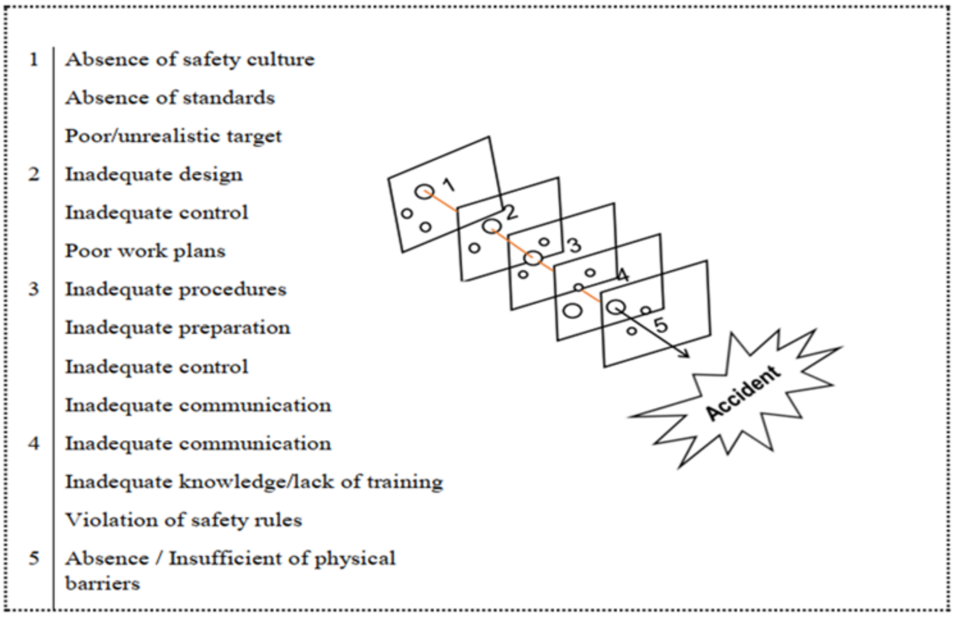

Figure 2-5: Swiss Cheese model (Godians & Ramachandra, 2018)

2.8. Accident sequence

According to (McKinnon, 2012), accidents are caused by a sequence of events, a combination of circumstances and activities that culminate in loss, similar to domino effect. The loss may be an injury, damage, or business interruption. Due to some unexplained circumstance, sometimes called fortuity or luck, the event does not end in loss and this is usually termed a near miss incident. The factors leading up to an accident are there, but the event is interrupted as there is no exchange of energy and, therefore, no injury, property damage, or loss.

2.8.1. Failure to assess the risk

The first factor in loss causation sequence is the failure to assess and mitigate the risk.

Risk assessment is a method that is predictive and can indicate potential for loss. With this statement, an organization is then able to set up the necessary management controls to prevent these risks resulting in losses, such as injuries, property damage, business interruptions, and environment pollution, this method of accident prevention entails examining near miss incidents, risk assessing, and ranking their potential and investigating and rectifying the root causes of the high-risk, near miss incidents.

Many safety programs focus on the consequence of loss and not the control. Effective risk assessment is proactive, predictive safety in the finest form. In risk assessment, the keywords are: “it’s not what happened, but what could have happened,”

2.8.2. Lack of control

Lack of control is the second link, this lack of safety management control could be no safety program, no safety program, no safety program standards, or noncompliance to the standards or lack of a structured safety management system. This triggers the basic causes of accidents. If no formal, near miss event reporting and investigation system is in place, this would be classified as an inadequate control system.

2.8.3. Basic causes or root causes

The basic (root) causes of accidents are categorized as personal and job factors.

They are the underlying reasons why high-risk acts are committed and why high-risk conditions exist. A personal factor could be a lack of skill, physical or mental incapability to carry out the work, poor attitude, or lack of motivation. Job factors could include inadequate purchasing, poor maintenance, incorrect tools, or inadequate equipment.

These basic causes then trigger the immediate causes that are unsafe work conditions and unsafe work practices (high-risk conditions and high-risk acts).

Immediate cause

<u>High-Risk conditions</u>

High-risk conditions are physical work conditions that are below accepted standards.

This results in a high-risk situation or an unsafe work environment.

High-risk work conditions include:

- Unguarded machines
- Cluttered walkways
- Poor housekeeping
- Inadequate lighting
- Poor ventilation

Near miss incident control will highlight high-risk practices and conditions before they result in an accident.

<u>High-risk acts</u>

High-risk acts are the behaviors of people that put them, and possibly others, at risk. In other words, this means this means that people are behaving contrary to the accepted safe practices and, thus, creating a hazardous situation that could result in a loss.

High-risk acts include:

- Working without authority
- Failure to warn somebody
- Not following procedures
- Rendering safety devices inoperative
- Clowning and fooling around in the workplace

Accidents and near miss incidents are always a result of multiple causes, normally a combination of high-risk conditions and practices, and seldom, if ever, is an accident or a near miss incident attributable to a single cause.

Natural factors account for a small percentage of accidents. Tornadoes, thunderstorms, volcano eruptions, earthquakes, and floods are examples of natural or environmental factors that can lead to major losses. These can neither be attributed to high-risk behavior nor an unsafe work environment. Taking up an unsafe position or tempting the elements would contribute to, or aggravate the severity of, a loss in a natural event, but does not cause the event itself.

2.8.4. Contact and exchange of energy

The high-risk conditions or acts give rise to an exchange of energy and a contact that is th stage in the accident sequence where a person's body or piece of equipment is subject to an external force greater than it can withstand, which results in injury or damage.

A luck factor exists here because the high-risk act or condition may only result in a near miss incident with no loss. There is no contact with the energy or the energy is insufficient to cause harm.

A near miss incident must have an energy phase or there is no near miss scenario. A high-risk act or condition does not constitute a near miss incident if there is not flow energy that could have contacted.

The energy phase must consist of a flow of energy and not merely potential energy. A suspended load has potential energy, but a worker walking under the load is not involved in a near miss incident. He is committing a high-risk act and the suspended load is a high-risk condition; no matter how secure the load is).

2.8.5. Injury, damage, or loss

After the contact and exchange of energy, luck again plays a role in determining the outcome of the contact. The outcome could be injury to people, damage to property, harm to the environment, or process interruption, or a combination. We have no control over the outcome of the contact. Once the process is in motion, no control activity whatsoever can determine the outcome, which could be minor injury, serious injury, negligible, or severe damage to property or even death.

2.8.6. Injury

If the contact results in an injury, we are again dependent on luck. The injury may be minor, disabling, or fatal. The outcome of the exchange of energy and subsequent injury is fortuitous and depends on luck. The end result of a contact cannot be predicted or controlled. Contact safety controls (at the time of the energy exchange), such as personal protective equipment, safety belts, and vehicle air bags, contribute to help reduce the severity of injuries that are hard to predict.

2.8.7. Property damage

One of the three major outcomes of a contact is property damage. Accidental property damage is damage caused by an accident, which does not result in injury or business disruption. Many safety programs do not call for the reporting or investigation of these damage accidents, which in most cases also have potential to cause injury to employees under different circumstances.

The damage is usually a result of a contact and exchange of energy greater than the resistance of the object. Property damage can include damage to buildings, floors, equipment, machinery, and material.

In referring to the accident rations, the property damage accident occurs more often than any other type of accident. Property damage accidents, therefore, are opportunities to identify the basic cause, and take steps to eliminate a similar accident occurring. It will be appreciated that should a similar accident occur, because of hazards that have been rectified, the outcome may be different, the next time the accident may result in injury, damage, business interruption, or a combination of all three.

Property damage accidents are the most important in the accident ratio. They also are warnings that a failure exists in the management system. This causes root causes to exist, which in turn, give rise to immediate causes and the contact, which then causes a loss in the form of damage to equipment, machinery, etc.

Most property damage accidents have the potential to injury people; therefore, they should not be ignored. All significant property damage accidents should be thoroughly investigated, and a costing done to indicate the actual losses incurred. Costs of repairs to equipment should be listed and tabled as well at the various safety committee meetings.

2.8.8. Loss

Each accident results in some form of loss and all losses cost money. Time may be lost, forms need to be filled out, and the business is interrupted to a degree. Many of the costs of an accident are hidden and, therefore, go unnoticed. Direct costs or insured costs are normally the only costs associated with an accident and are the lesser of the two amounts.

2.8.9. Costs

The final phase of the accident sequence and the last link in the chain reaction are costs.

All contacts and exchange of energy result in some form of loss. Losses could include both direct and indirect costs of the accident. In mining and industry, property damage costs could be up to 50 times greater than the direct costs of accidents. A third cost is the totally hidden costs that are seldom identified or tallied. The totally hidden costs of the accident are also losses that hard to determine, but that exists, nevertheless.

Part of the management control function would be costing out the accidental losses and showing these as part of the losses of the business. Well-known management consultants have stated that maximizing profits is not the only aspect of business, as minimizing losses is just as important.

2.9. Quantitative aspects of risks

The risk can be defined using two basic formulas as follows:

$$\mathbf{Risk} = \mathbf{Probability} \times \mathbf{Consequence} \qquad \textit{Equation 4}$$

Or alternatively;

$$\textbf{Risk} = \textbf{Frequency} \times \textbf{Severity} \qquad \text{Equation 5}$$

We can calculate the risk using the estimated or measured value or the two parameters in the equation, as there is no absolute measure. The units are in terms of money, loss of life, or ecological or environmental damage.

2.10. Tools in risk maintenance

In manufacturing industry there are various kind of risk management tools been deployed to resolve cases of such like downtime, long time spent during production activities and same time increasing safety and productivity (Godians & Ramachandra, 2018). Different kinds of risk tools are listed below with its scope of use and applicability in various industries types.

2.10.1. Fault Tree Analysis – FTA

FTA is used to identify an undesirable event which is known to be top event associating with set of events interconnected in a network form called a system or problem. In this phenomenon of the events liable in causing the emerging of the top event are obtained and connected by logic gates called OR, AND, etc. typically, a fault tree is meant to be events in a successive arrangement flow reaching the time fault events stopped to develop more or further (Godians & Ramachandra, 2018).

FTA method is known as failure or negative events, which may simply describe as logic arrangement relating the top event to the basic fault events. In figure 2-4 is illustrated the four commonly used symbols in fault tree construction. The circle a) denotes a basic fault event or the failure of an elementary component; the event's occurrence probability and failure and repair rates are normally obtained from empirical data. The rectangle b) denotes a fault event that results from the combination of fault events through the input of logic gate. The OR gate c) denotes that an output fault occurs if one or more of the input fault events occur. Finally, the AND gate d) denotes that an output fault event occurs only if all the input fault events occur.

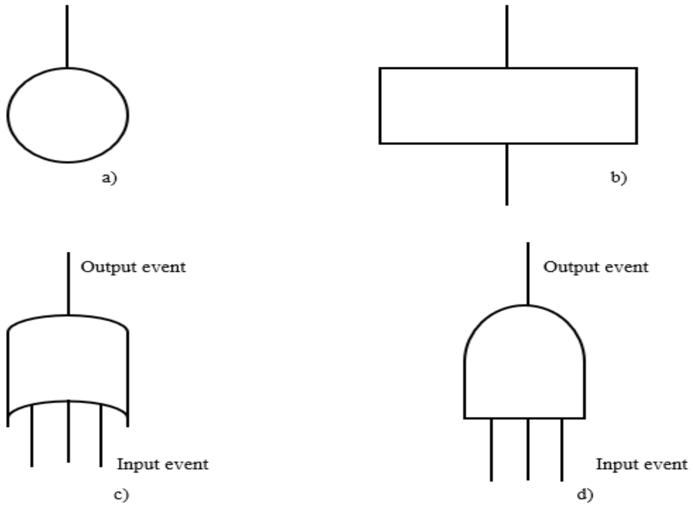

Figure 2-6: Commonly used fault tree analysis symbols.

FTA is taken as an analytical technique that is used to trace the chronological progression of factors (events) contributing to the accident situation, and is useful in accident investigation and as a predictive, quantitative model in risk assessment (Ridley & Channing, Safety at work, 2008).

2.10.2. Hazard Operation Analysis – HAZOP

A method used in examining complex or process or operation to identify and evaluate resulted effect of a problem which cause risks to component or to personnel at work. HAZOP are widely used in some industry and its structured pattern is bottom-up which uses combination of design parameters to identify deviation. The whole concept involves investigating how a system or subsystem deviated from the original design. When the investigation identifies the cause of the problem, the recording event will resume to make sure proper attention for a solution is given to reduce furtherance occurrence or a way of upgrading the control of instrumentation system. HAZOP process is systematic in use to explain the terms such like study nodes, intention, deviations, causes and consequences, in the process of the investigations.

2.10.3. Failure Modes and Effects Analysis (FMEA)

Even if we are able to identify all the required functions of a functional block, we may not be able to identify all the failure modes. This because functional may have several failure modes. No formal procedure seems to exist that may be used to identify and classify the possible failure modes (Rausand & Hoyland, 2004).

Before we start on this subject, is essential set up the difference between failure, fault and error so that we can't misunderstand them.

According to IEC50(191) Failure is the event when a required function is terminated (exceeding the acceptable limits), while fault is "the state of an item characterized by inability to perform a required function, excluding the inability during preventive maintenance or other planned action, or due to lack of external resources." A fault is hence a state resulting from a failure.

According to IE 50(191) an error is a "discrepancy between a computer, observed or measured value or condition and the true, specified or theoretically correct value or condition." An error is (yet) not a failure because it is within the acceptable limits of deviation from the desired performance or target value.

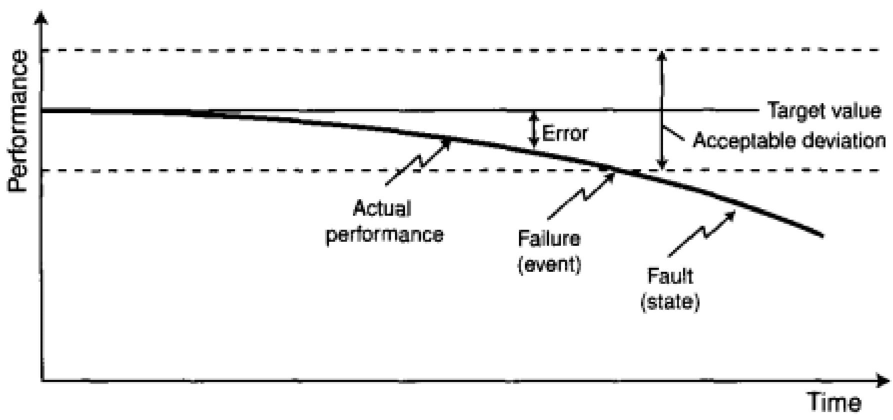

Figure 2-7: Illustration of the difference between failure, fault, and error (Rausand & Hoyland, 2004).

Failure modes of each component are identified using appropriate risk measure, it is known that for a complex or noncomplex set, each component has its own constitution and reliability. Therefore, the most common criteria used to rank the criticality of a component functional failure are related to their impacts on safety, availability and maintenance costs. It is very important to record all failure mode of each component for further study of the system behavior in term of reliability.

FMEA, is used to analyze system to determine what the effects of individual components might be on the entire assembly or system (Kim, Singh, Sung, Park, & Lee, 1996). At first, major assemblies of the system are listed, after which each assembly is broken down into its component elements. Each component is then studied to see how it could fail, what could cause each type of failure, and the effect of this failure on other components, subassemblies, and the entire product. FMEA is a tool to systematically analyze all contributing component failure modes and identify the resulting effects on the system.

A significant danger in using FMEA is that the engineer will think that by identifying failures he or she has identified hazard causes (Bahr, 2015).

2.10.4. Criticality Analysis (CA)

CA provides relative measures of significance of the effects of a failure mode, as well as the significance of an entire piece of equipment or system, on safety, successful operation and missions requirements. In essence, it is a tool that ranks the significant of each potential failure for each component in the system's design based on a failure rate and a severity ranking. This tool is used to prioritize and minimize the effects of critical failure early in the design.

The worksheet for FMECA is very useful to decide the maintenance policies for component. If any new failure occurs during maintenance period, it should be entered into the worksheet of FMECA and how to detect this failure is also to be mentioned.

2.10.5. Failure Modes Effect and Criticality Analysis – FMECA

The Failure Mode, Effect and Criticality Analysis (FMECA) is a reliability evaluation/design technique which examines the potential failure modes within a system and its equipment, in order to determine the effects on equipment and system performance. Each potential failure mode is classified according to its impact on mission success and personnel/equipment safety (RAC, 1993).

The FMECA is composed of two separate analyses, the Failure Mode and Effect Analysis (FMEA) and the Criticality Analysis (CA); the FMEA must be completed prior to performing the CA.

2.10.6. Root Cause Analysis –RCA

It is performed in way to evaluate failure and take actions of isolating the cause of the resulted to event intending to cause main failure; it is done in a logical sequencing and by through iterations of investigations, this is done when incident has occurred and recorded. As a result, obtained the event occurrence are classified on the type or sources of failure that brought the occurrence whether safety caused event, or equipment failure etc. Data are mainly generated and evaluated through method of cause chain and identify immediate, source of contributing the negative event, and the tracing of root cause are then conducted. Hence to resolve the problem it follows some sequences in simplifying the cause in order to determine exact maintenance actions in corresponding order.

2.10.7. Indexing Methods – IM

On this IM the risk method analysis is done in such ways of comparative risk levels where evaluation is being deployed. The method simply made to be each design is denoted in many multiple ways dependent on the factors attributed to the whole risk. To lay emphasis of a well design process which uses highly toxic substance can be noted to be negative point, while another facility than is place or located distance far from populated are receives positive points.

2.11. Ergonomics in maintenance

Ergonomics is just a study of human work which is very vital to design the work to facilitate the workers to operate easily. The main intention is to reduce the physical force on the operator's body thereby simplified tasks, effective design of workstations, easy access of required tools and equipment's will help in reducing physical stress on the worker's body. Due increase in productivity in all industries across the globe frequent lifting, carrying excessive load for prolonged duration of time, pushing and pulling are common activities performed in industries therefore, the focus is to reduce work related musculoskeletal disorders (WMSD's) or MSD's, associated because of poor ergonomic design hence, it is very essential to reduce and avoid the workload and improve employee health and safety (OSHA 2000, as cited in Godians & Ramachandra, 2018).

Michaud (2017) defined ergonomics or human factors as the study of the anatomical, psychological, and physiological aspects of a human being in a working environment. Its objective is to optimize human safety, health, comfort, and efficiency.

In other words, both definitions express that ergonomics can maximize the worker to increase productivity, job satisfaction, and job attitude. When this happens, injuries will be minimized, and hazards will be practically eliminated. And we can understand that ergonomics seeks to prevent WMSDs by applying all logical principles to identify, evaluate, and control physical workplace risk factors.

WMSDs are also known as cumulative trauma disorders (CTDs), repetitive strain injuries (RSIs), repetitive motion trauma (RMT), of occupational overuse syndrome. Examples of WMSDs include epicondylitis (tennis elbow), tendinitis, DeQuervain's disease (tenosynovitis of the thumb), trigger finger and Reynaud's syndrome (vibration white finger). Carpal tunnel syndrome (CTS) is a commonly known WMSD as is back strain. Occupational Safety and Health Association (OSHA) uses the term MSD (Stack, Ostrom, & Wilhelmsen, 2016).

MSD's are disorders or injuries effects on soft tissues with effects on muscles, tendons, strains, tissues injuries etc, this leads to pain, numbness, muscle loss and in rare case of paralysis. The primary cause of MSD's is when the workers physical capabilities does not fit with job requirements therefore it leads to injury on workers body. According to OSHA the major MSD risk factor are:

- ✓ Forceful work
- ✓ Repetition of tasks
- ✓ Uncomfortable positions
- ✓ Prolonged stationary positions
- ✓ Stress contact
- ✓ Vibration
- ✓ Hot or cold temperatures

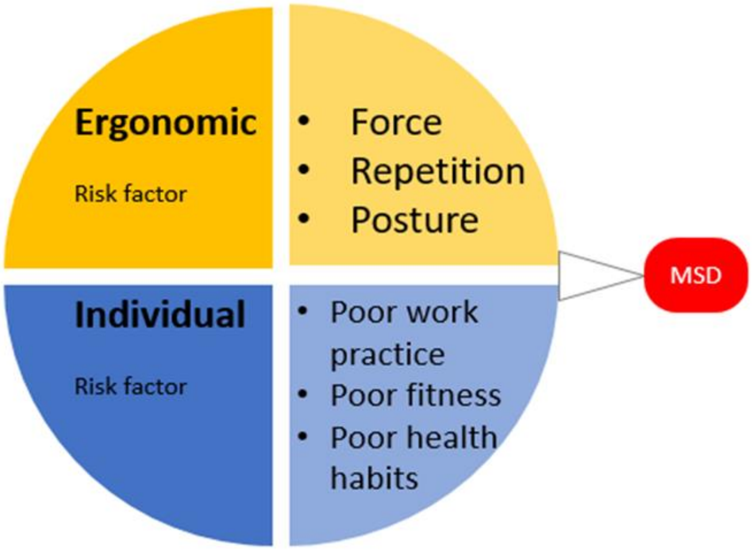

Figure 2-8: Work related ergonomic risk factor, adapted from (Godians & Ramachandra, 2018).

Researchers have identified specific physical workplace risk factors involved in the development of WMSDs. Exposure to these risks factors can result in:

- Decreased blood flow to muscles, nerves, and joints;
- Nerve compression;
- Tendon or tendon sheath damage;
- Muscle, tendon, or ligament sprain or strain; and
- Join damage.

Prolonged exposure to the physical workplace risk factors can lead to permanent damage and a debilitating condition. When present for sufficient duration, frequency, or magnitude, physical workplace risk factors, such as physical conditioning, existing heath problems, gender, age, work technique, hobbies, and organizational factors (job autonomy, deadlines) contribute too but do not cause the development of WMSDs. Applying ergonomic principles to reduce a worker's exposure to the physical workplace risk factors decreases the chance of injury and illness.

2.11.1. Physical Workplace risk factors

Physical workplace risk factors are those aspects of a job or task that impose biomechanical stress on a worker. MSD risk factors are the objective characteristics of the work environment that affect the demands on the person. The higher the stresses of the task or the more stressors present in a job, the higher the demands on the person and the greater the chance for an injury (Roquelaure, 2018). Regardless of the type of work being performed, research has shown that the key stressors to look for in an ergonomics evaluation are:

Force: Under normal conditions, muscles can produce enough force for motion. However, if the muscles are overused, which generally involves the generation of either high or sustained levels of force, then extreme fatigue may occur which may lead to MSDs. According to OSHA, force refers to the amount of physical effort that is required to accomplish a task or motion. Tasks or motions that require application of higher force place higher mechanical loads on muscles, tendons, and joints and can quickly lead to fatigue.

The force required to complete a movement increase when other risk factors are also involved. For example, more physical effort may be needed to perform a task when speed is increased or vibration present. Performing forceful exertions requires the application of muscle contraction that may cause them to fatigue quickly.

The power zone for lifting, with the greatest strength, endurance and control, and lowest risk of injury is holding the load close to the body between the knuckle and shoulder height.

Posture: the body functions are better when it is in a neutral posture – located around the joint's midrange of motion for most body parts. An exertion significantly outside this neutral range, termed an awkward or extreme posture, is efficient and requires muscles to work near their maximum capacity which may result in increased fatigue rate and MDSs.

The neutral posture is the optimal body position in order to minimize stress and provide the greatest strength and control. The neutral posture is the body position in which there is the least amount of tension or pressure on the nerves, tendons, muscles, joints, and spinal discs.

Movement: the best way to look at static loading and repetitive motion is to think of the concept of movement. Some movement is good and necessary for the body in order to promote circulation. Too little or too much movement in a task can be harmful to the body. Either of these extremes can contribute to the development of MDSs.

Work environment: the working environment exposes the worker to a variety of different factors that affect the way the body works, and which can also increase the likelihood of MSD development. These environmental factors include cold temperatures, hot temperatures, noise, lighting, vibration and pressure on soft tissue known as contact stress.

Magnitude, Frequency, and Duration: three subcategories of stressors play a role in the overall level of risk associated with those MSD stressors already mentioned. As the magnitude (how much) of a stressor increases, so does the likelihood of developing an MSD. Similarly, the higher the frequency (how often) or the longer the duration (how long) a stressor occurs, the higher the risk involved. In many real-world scenarios, MSD stressors cannot be completely eliminated, but most times changes can be made to reduce a stressor's magnitude, frequency and duration, thereby reducing the overall amount of risk for the task at hand.

Force, repetition, and awkward posture, especially when occurring at high levels or in combination, are most often associated with the occurrence of WMSDs. While exposure to one risk factors may be enough to cause injury, typically physical workplace risk factors act in combination to cause injury. Other workplace conditions can contribute to but do not cause WMSDs. They can however cause other undesirable health conditions.

Individual risk factors include:

- ✓ **Poor work practices**. Workers who use poor work practices, body mechanics and lifting techniques are introducing unnecessary risk factors that can contribute to MSDs. These poor practices create unnecessary stress on their bodies that increases fatigue and decreases their body's ability to properly recover.

- ✓ **Poor overall health habits**. Workers who smoke, drink excessively, are obese, or exhibit numerous other poor health habits are putting themselves at risk for not only musculoskeletal disorders, but also for other chronic diseases that will shorten their life and health span.
- ✓ **Poor rest and recovery**. MSDs develop when fatigue outruns the workers' recovery system, causing a musculoskeletal imbalance. Workers who do not get adequate rest and recovery put themselves at higher risk.
- ✓ **Poor nutrition, fitness and hydration.** For a country as developed as the United States, an alarming number of people are malnourished, dehydrated and at such a poor level of physical fitness that climbing one flight of stairs puts many people out of breath. Workers who do not take care of their bodies are putting themselves at a higher risk of developing musculoskeletal and chronic health problems.

The most important component in any work application is the people who are directly involved in the task. Most tasks require only basic adjustment in order to improve working condition. Maintenance works are the group that require great attention to ensure maximum productivity, and at the same time, a great assurance of safe conditions.

Standardization in the field of human factors and ergonomics for the design and evaluation of consumer products and work systems, including task, jobs, tools, equipment, organizations, services, facilities and environments, in order to make them compatible with the characteristics, the needs and values, and the abilities and limitations of people.

Therefore, we can understand that human factors call for a multidisciplinary science.

Maintainability in general is a procedure in the process for design of system or product in which designers need to go through with the aim of having more maintainable and reliable, high quality, easy to use and higher durable functionality of their design in order to meet in-tended user requirement (Teymourian, Seneviratne, & Galar, 2017).

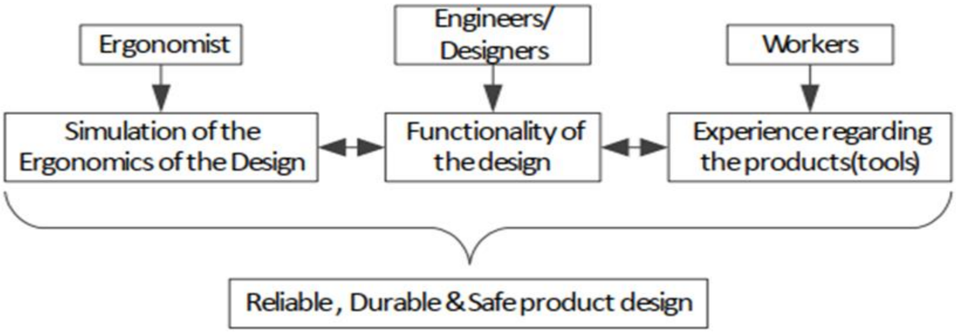

Figure 2-9: Product design work flow (Teymourian, Seneviratne, & Galar, 2017).

Ergonomics has a great participation when dealing with hazards and risks. As a multidisciplinary approach the ergonomics set up in a satisfactory condition the requirement of the both sides. to have a better work environment it's necessary first start with an ergonomic approach to conduct all needs in term of safe. Therefore, it is necessary to examine the physiology of work and fatigue, the physical structure of the person, the tool design, the work layout, the task, and the environment hazards of the operation.

Thus, we have the man-machine-environment system. Fitting the worker to the job and workplace in the most cost-effective manner requires analysis of human physical and psychological needs and adjustment or redesigning of tasks and tools to account for individual differences.

It begins simply by observing the task, the worker, and the work environment, then analyzing each movement or position particular to the task. Proper lighting, rest periods, noise, temperature, and ventilation must be assessed because they all contribute to worker fatigue.

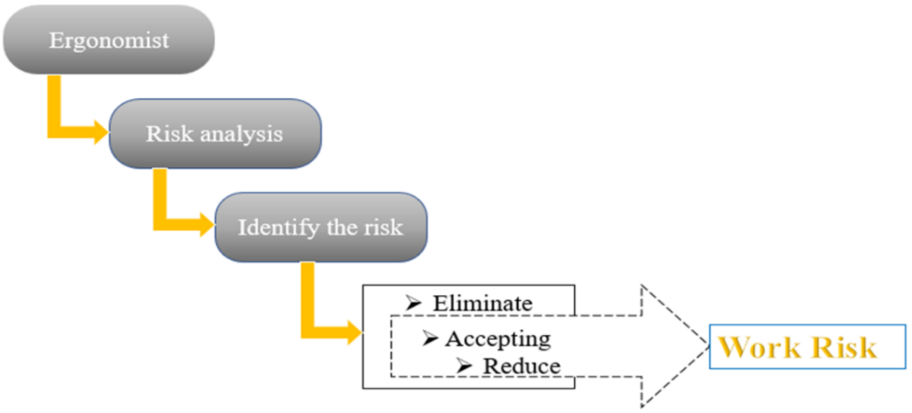

Figure 2-10: Role of ergonomist participation

When the task has been optimally fitted to the person using ergonomic principles, several benefits can occur:

- ✓ Reduced lost work-time illnesses and injuries
- ✓ Reduced worker's compensation costs
- ✓ Reduced training/retraining costs
- ✓ Increased levels of productivity, efficiency and quality
- ✓ Improved comfort of employees through proper equipment uses
- ✓ Reduced long-term equipment costs by incorporating ergonomics specifications into purchasing
- ✓ Increased employee morale by providing a safer and healthier work environment.

2.12. Job Safety/hazard Analysis

(Reese, 2012) describes a job safety/hazard analysis (JSA/JHA) as a procedure that integrate accepted safety and health principles and practices into a specific task or job procedure. In a JSA/JHA, each basic step of the job is to identify potential hazards ad to recommend the safest way to do the job. Jobs that should have JSA/JHA conducted on them and receive attention first are:

- Jobs with the highest injury or illness rates
- Jobs with the potential to cause severe or disabling injuries or illnesses, even if there is no history of previous accidents
- Jobs in which one simple human error could lead to a severe accident or injury
- Jobs that are new to the operation or have undergone changes in processes and procedures
- Jobs complex enough to require written instructions

Therefore, we can easily say that JSA/JHA is a basic approach to developing improved accident prevention procedures by documenting the first-hand experience of workers and supervisors and, at the same time, it tends to instill acceptance through worker participation. JSA/JHA can be a central element in a safety program; and the most effective safety programs are those that involve employees.

2.12.1. Performing a JSA/JHA

Some basic questions are asked to perform a JSA/JHA:

- What can go wrong?
- What are the consequences?
- How could it happen?
- What are the contributing factors?
- How likely is it that the hazard will occur?

The answers to these questions will help in hazard identification. Some of the other accident specific questions are:

- Can any body part get caught in or between objects?
- Do tools, machine, or equipment present any hazards?
- Can the worker make harmful contact with moving objects?
- Can the worker slip, trip, or fall?
- Can the worker suffer strain from lifting, pushing, or pulling?
- Is excessive noise or vibration a problem?
- Is the worker exposed to extreme heat or cold?
- Is lighting a problem?
- Can weather conditions affect safety?
- Is harmful radiation a possibility?
- Can contact be made with hot, toxic, or caustic substances?
- Are there dusts, fumes, mists, or vapors in the air?

2.13. Guideline for risk matrix application

The semi-quantitative risk assessment method defines risk as the probability or likelihood that an event or incident will occur. The probability and consequence are estimated to give:

$$\textbf{Risk Rating} = \text{SEVERITY} \times \text{FREQUENCY} \times \text{DETECTABILITY} \times \text{PROBABILITY} \quad \textit{Equation 6}$$

$$\textbf{Residual Risk Rating} = \boldsymbol{SEVERITY \times FREQUENCY \times EXPOSURE\ (Impact) \times PROBABILITY} \quad \text{Equation 7}$$

The estimated risk can be represented in the form of a matrix, and this is referred to as a Risk Matrix. The seriousness of the risk can be determined and presented as critical- priority 1-C, Priority 2 – P2, (Monitor control in time) and Insignificant - L.

Table 2-3: Risk matrix criteria, Source: Coca-Cola (2021).

C	FRG >= 50	Priority 1
P2	10 < FRG < 50	Priority 2
L	FRG =< 10	Controlled risk

Table 2-4: Actions after scoring risk matrix, Source: Coca-Cola (2021)

Action to be taken after scoring:		
SCORE (RF)	ACTION TO BE TAKEN	ACTION TO BE TAKEN
>50	**Priority 1** Significant Risk– Critical Priority	
11-50	**Priority 2** – Monitor and control in time	
<10	**Priority 3** – Low Risk ,Tolerate	

The Consequence and Likelihood/Probability parameters are described for Safety and Health, Environmental, Financial and Business Continuity risks in terms of different criteria; Residual risk is the threat that remains after all efforts to identify and eliminate risk have been made, there are four basic ways of dealing with risk: reduce it, avoid it, accept it or transfer it.

CHAPTER III: RESEARCH METHODS AND STRATEGIES

3. RESEARCH METHODS

For the present study, was used two main pillar which was the bibliographic review and data collection made at Coca-Cola Company – Chimoio; the bibliographic review was used to support data analyses and involved books, dissertations, company standards and annual reports that the company produce. And for the data collection was possible to collect through the company's annual data.

This research can be considerate having exploratory objectives with applied nature because it results in a production or solving a problem. The approach is regarded to a mixed attitude which join the qualitative and quantitative (Vianna, 2020).

For data analyses were used different tools to process each kind of data which was collected. The tools used were: FMECA and Fault Tree Analysis. With these powerful tools enabled to analyze the level of hazard and find out the highest hazard operation.

3.1. FMECA

The risk ranking in the FMECA was made to access the level of hazards in each machine and component so that the highest risk could be detected in the maintenance process. Therefore, the equation 5 was used to develop the whole FMECA and the table 2-3 was used as the risk matrix criteria and table 2-4 was used to decide what action are required to reduce the risk.

3.2. FTA

The FTA was developed to understand the human error when operating a maintenance activity. The common factors which are involved in second call maintenance. To build the FTA, first we analyzed the root cause of the frequent accidents found; figure 2-6 was used to make the graphic representation of the associated FTA and all the probability together.

CHAPTER IV: RESULTS AND DISCUSSION

4. INTRODUCTION

All data collected was based on work condition and risk, as all machine interacts with human.

4.1. Data collection

The data were collected for each machine in the production lines to produce the FMECA and the FTA. The parameters of normal working and the regular tasks of maintenance operation were collected to analyze what are the critical and priorities when the tasks are being launched.

4.2. Survey data collection

The data collection result of survey section is according to each machine in the productions line and the different kind of risks. Therefore, the data numbers to produce the tables were taken only from the risk factor (because this is the result product of severity, frequency, probability and detectability).

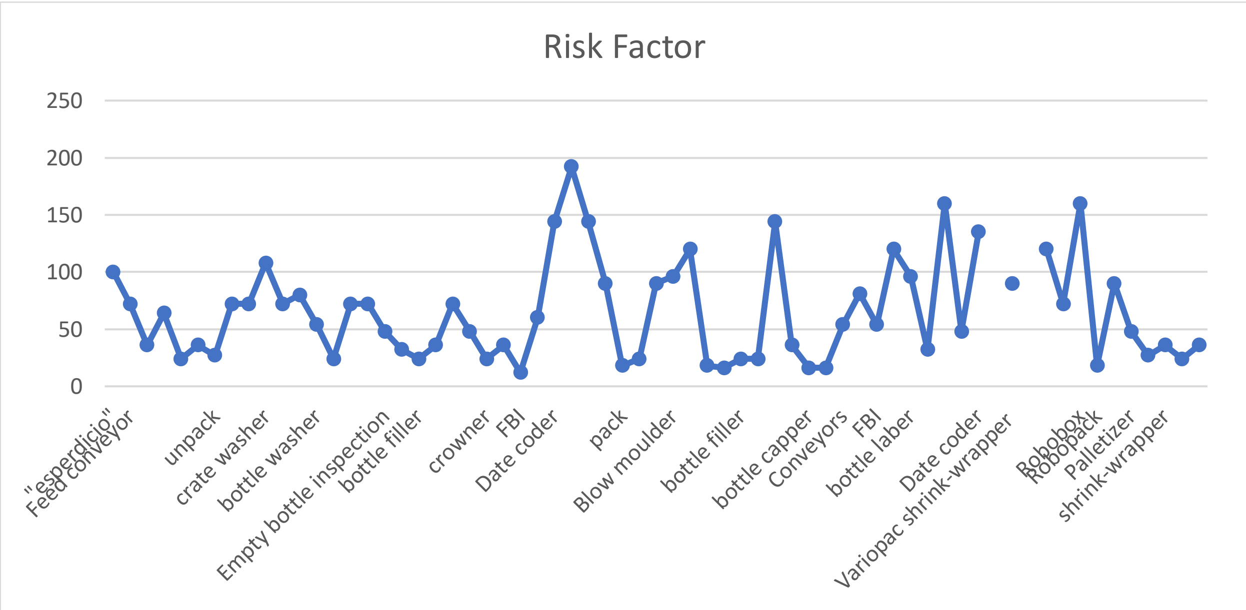

Figure 4-1: Risk factor – by Machines.

As been demonstrated in figure 4-1, the highest risk is located in the dater coder machine in RGB line, this risk come from the product used on it. The other data coder (PET) doesn't have the same risk because it uses laser to code the bottles. The bottle labeller also is in a critical range due to the material which are handled.

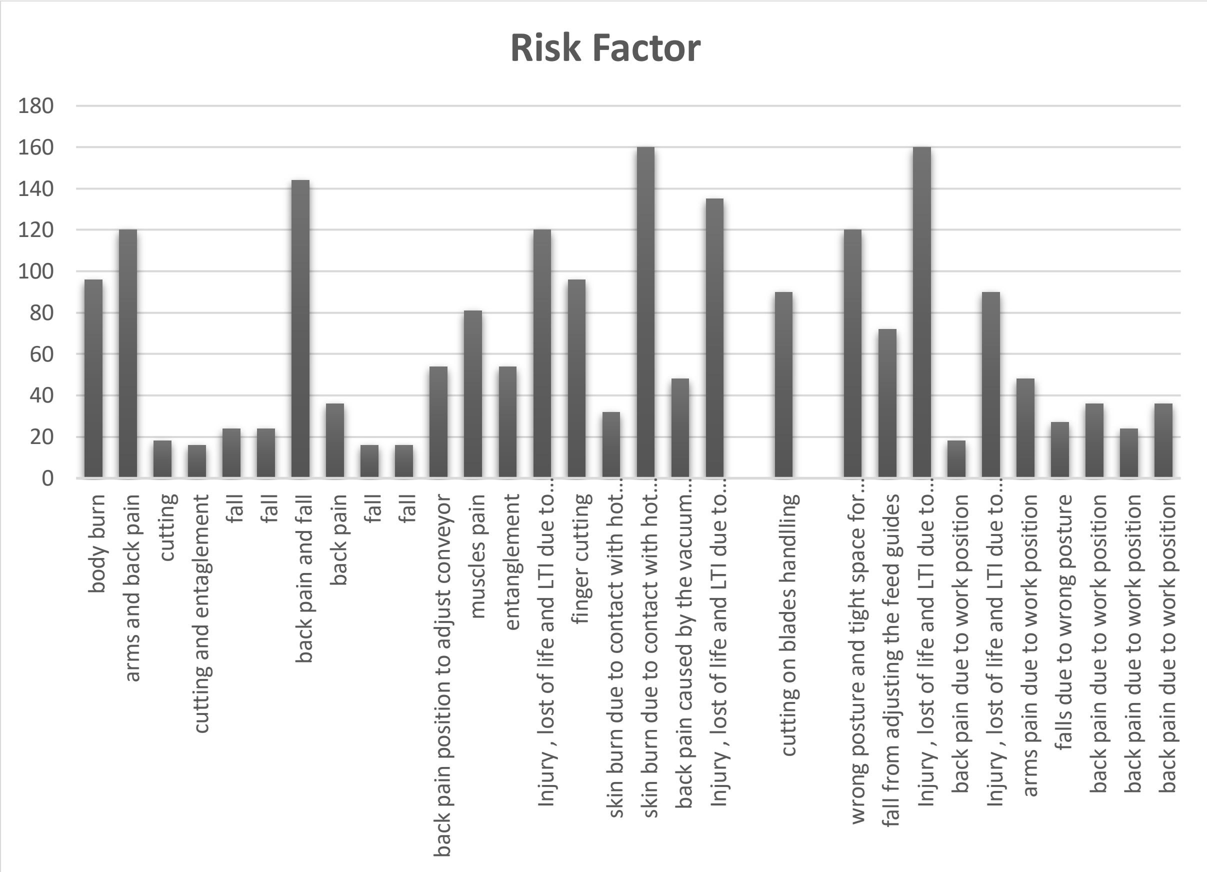

Figure 4-2: Risk factor - by risk

The figure 4-2 show clearly where and what is the highest risk. This scoring comes to due to the environment degradation that can occur from the wrong handling or misuse. The electrical part is also a dangerous process that can be deadly on maintenance operations.

The annexes A and B show the FMECA where this graphics showed had been generated. I the FMECA is important to notice that “esperdicio” was ranked as 5 on the frequency, this because it’s used in all maintenance activities and it is very necessary; used during and after maintenance to clean the process parts. Data coder at RGB due to the necessity of changing the bottles of ink to coding also has a high ranking on frequency.

For PET line the frequency is high in the Blow Molder, Variopack and Bottle laber. Blow Molder has this frequency due to the constant molder changing for the bottle size; as the same when changing the molder to produce different bottle sizes, the guides in the bottle laber need to be changed also, therefore this increase the frequency on the process.

Also, the FTA where developed to help identify potential causes of the system failures before the failures occur. Therefore, by doing this was possible to evaluate the probability of the top event for RGB line and PET line using statistical and analytical method.

The calculations of the probabilities for both line involved system quantitative reliability and maintainability information, such as failure probability failure rate and repair rate.

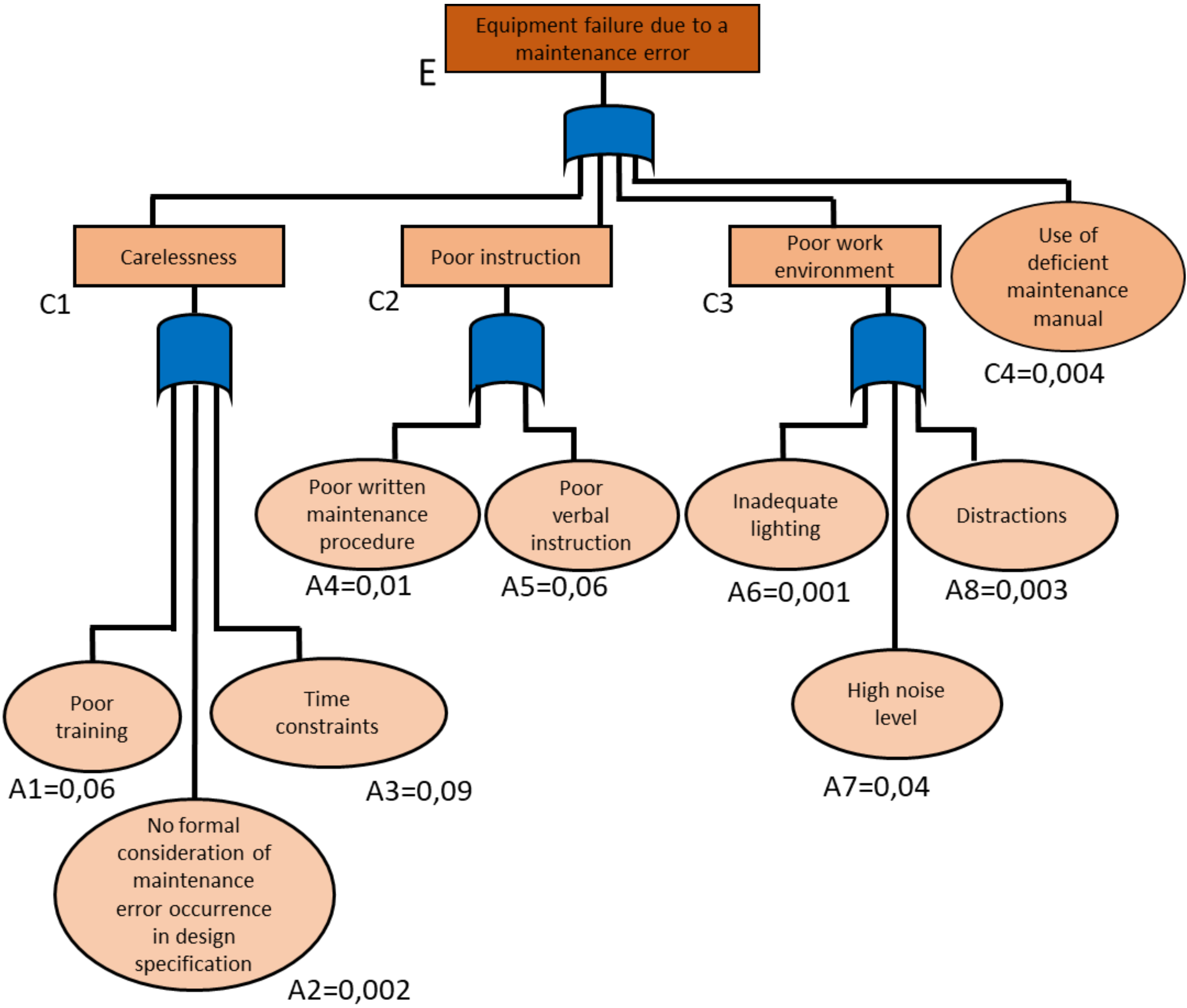

Figure 4-3: Fault Tree Analysis for maintenance error

To calculate the top event E (equipment failure due to maintenance error) we started to find out the probability of the lowest level. Therefore, we calculate the C_1, C_2 and C_3 to determine the probability to occurrence the top event.

$$P(C_1) = 1 - [(1 - P(A_1)) \times (1 - P(A_2)) \times (1 - P(A_3))]$$

$$P(C_1) = 1 - [(1 - 0.06) \times (1 - 0.002) \times (1 - 0.09)]$$

$$P(C_1) = 0.146$$

$$P(C_2) = P(A_4) + P(A_5) \ - \ P(A_4) \times P(A_5)$$

$$P(C_2) = 0.01 + 0.06 - 0.01 \times 0.06$$

$$P(C_2) = 0.069$$

$$P(C_3) = 1 - [(1 - P(A_6)) \times (1 - P(A_7)) \times (1 - P(A_8))]$$

$$P(C_3) = 1 - [(1 - 0.001) \times (1 - 0.04) \times (1 - 0.003)]$$

$$P(C_3) = 0.043$$

$$P(E) = 1 - [(1 - P(C_1)) \times (1 - P(C_2)) \times (1 - P(C_3)) \times (1 - P(C_4)]$$

$$P(E) = 1 - [(1 - 0146) \times (1 - 0.069) \times (1 - 0.043) \times (1 - 0.004)]$$

$$P(E) = 0.242$$

This probability can be considerate high and can decrease the lifecycle of the equipment, therefore we calculate the human reliability probability to understand the correct way to reduce the probability.

Using the table 2-1 to determine the human reliability probability with second operator in the first 5 minutes that are not recorded as breakdown and it has more time pressure, we get the joint HEP and applying the equation 2:

$$\textbf{Human reliability probability} = 1 - \text{HEP}$$

$$\textbf{Human reliability probability} = 1 - 0.002$$

$$\textbf{Human reliability probability} = 0.998$$

CHAPTER VI: CONCLUSIONS AND RECOMMENDATIONS

5. INTRODUCTION

5.1. Conclusion

To achieve a better smart industry which allow an optimization is necessary to determine good ways to use risk management tools in maintenance operation to reduce the gaps which may occur between risk management and maintenance in order to increase safety and production.

Maintenance can be used to improve production through a focal point for equipment's availability, the usage of RAMS to predict the breakdowns and yield rate of each production line. Performing a "perfect" preventive maintenance in a manner to reduce the breakdowns avoid production disturbance and putting the safety first.

Risk management singles out production disturbances in more detailed form and categorizes them according to the degrees of occurrences and its effect and provide measures to eliminate these production disturbances in low cost-effective way, due to the background of such disturbance was followed-up to know the type of efforts needed to cushion the effect, in order, not be seen in the system.

As seen before, maintenance workers are more exposed to risk than production workers because of the nature of task. By reducing the breakdowns or imperfect repairs the exposure can be minimized avoiding constant and exhaustive recalls.

This research brings forth in one-line different issues faced in industries related to production disturbances; it provides ways of risk management applied in maintenance activities to achieve high productivity by reducing production disturbance.

5.2. Recommendations

Taking a base in the topics discussed all along the research, to keep moving in improvements to achieve desirable production and profitability through maintenance after seeing the structure of the company, is recommended to:

- Develop a software which will provide the reliability of each equipment online so that the breakdowns can be foreseen and to find out when to do the preventive maintenance instead of fixing the days of maintenance.
- Allow a constant and specified safety training for the maintenance workers so that they can apply better safety culture and maintenance culture regarded to different kind of hazards faced in maintenance activities.
- Have a safety officer specialized in maintenance activities to monitor and make sure that all procedure and risk tools are being applied in a right way.

NOMENCLATURE

Abbreviation	***Description***
ASSE	American Society of Safety Engineers
CTDs	cumulative trauma disorders
CTS	Carpal tunnel syndrome
RGB	returnable glasses bottles
OSHA	Occupational Safety and Health Association
PET	polystyrene
PSF	Performance-shaping factors
TPM	Total Productive Maintenance
RMT	Repetitive motion trauma
RSIs	Repetitive strain injuries
RCM	Reliability Centred Maintenance
RAMS	Reliability, Maintainability, Availability, Safety
FTA	Fault Tree Analysis
FMECA	Failure Method, Effect and Critical Analysis

KEY WORDS

1. Risk
2. Hazard
3. Dependence
4. Maintenance
5. Reliability
6. Ergonomics

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APPENDIX A: FMECA - RGB

Zone	Equipment/Process	Requeriment	Hazardous task/activity	Hazards/aspects	Risk/impact	Heath, Safety, Environmental	Frequency	Severity	Probability	Detectability	Risk Factor	Significant	Hierachy of control
-	"esperdicio"	clean	usege	not recyclible	Environment pollution	E	5	4	5	1	100	C	Engineering controls
RGB	Feed conveyor	Drive bottles across the sections	change bearing	hard access to the bearing	cutting	S	4	3	3	2	72	C	Training
			Lubrification	wet floor	body Injury due to falling from the conveyor lubrification process	S	3	2	3	2	36	P2	Administrative controls
			Person movement	Passing under conveyors	Back injury due to respective bending	S	4	4	4	1	64	C	Administrative controls
					Back injury due hitting of the back on conveyors and conveyors guides	S	2	2	2	3	24	P2	Administrative controls
			adjust conveyor's length, pulley	Conveyors handling	cutting due the shape of conveyorys	S	3	3	2	2	36	P2	Training
	unpack	remove bottles from crate	chang springs	kinetic energy	entanglement	S	1	3	3	3	27	P2	Administrative controls
			change bottle holders	ergonomics	back pain	S	3	4	3	2	72	C	Administrative controls
			adjust sensors	contact with electricity	Eletrocussion	S	2	4	3	3	72	C	Administrative controls
	crate washer	Clean crates	Change pully	Hot liquids	burn with the hot liquids	S	3	3	4	3	108	C	Administrative controls
			adjust conveyor's length	Work ay height	fall	S	3	3	4	2	72	C	Engineering controls
			Lubrifiction	Eletrocution	Injury , lost of life and LTI due to electrical shock by contacting with live equipments	S	2	5	4	2	80	C	Administrative controls and PPE
	bottle washer	Clean bottles	Change filters	work at height	fall	S	3	3	3	2	54	C	Administative controls
			Climb stears	work at height	slip	S	2	2	3	2	24	P2	Administrative controls
		Purify bottles	Change guides of bottle feed	ergonomics	back pain	S	3	3	4	2	72	C	Administrative controls
			change bearing	ergonomics	back pain	S	3	3	4	2	72	C	Administative controls
	Empty bottle inspection	detect dirty	Adjust sensors	ware cutting	cutting	S	2	2	3	4	48	P2	Administrative controls
		detect crack	Remove cracks	sharped glasses	cutting	S	2	2	4	2	32	P2	Engineering controls
	bottle filler	Fill up bottles	adjust the hummers	ergonomics	taut arm	S	1	2	4	3	24	P2	Administrative controls
			adjust feed caper	Work at height	fall	S	2	3	3	2	36	P2	Administrative controls
			Lubrifiction	ergonomics	back pain and fall	S	4	3	3	2	72	C	Engineering controls
			change bearing	Shape of conveyor	cutting due the sharped shape of conveyors	S	2	2	4	3	48	P2	Administrative controls
	crowner	Put capers in bottles	adjust the hummers	work at heigh	fall from adjusting the caper guide	S	2	2	3	2	24	P2	Administrative controls
			change bearing	work with conveyor and hummer	cutting	S	2	2	3	3	36	P2	Administrative controls and PPE
	FBI	Inspect full bottles	change hummers	work in tight space	entanglement	S	1	2	2	3	12	P2	Administrative controls
			adjust/remove sensors	contact with electricity	Injury , lost of life and LTI due to electrical shock by contacting with live equipments	S	2	5	3	2	60	C	Administrative controls and PPE
	Date coder	put data and code in bottles	Adjust and add ink	Video jet ink solution	Environment degradation due to spill of ink solution	E	4	4	3	3	144	C	Administrative controls
				Video jet solutions	respiratory illness due to inhalation of vapors	H	4	4	4	3	192	C	Training
					Skin burns due to contact with solution	S	3	4	4	3	144	C	PPE
			sort electric cables	High voltage (312 V) when charging batteries	Lost of life, desability due to electric shock	S	2	5	3	3	90	C	Administrative controls and PPE
	pack	sort bottles in crates	chang springs	kinetic energy	entanglement	S	1	3	3	2	18	P2	Administrative controls
			change bottle holders	ergonomics	back pain	S	2	3	4	1	24	P2	Administrative controls
			adjust sensors	Electrical shock	Electrocution that will cause cardiac arrest, LTI, desable, serious body injury due to handling non isolated equipment (Live)	S	2	5	3	3	90	C	Administrative controls and PPE

APPENDIX B: FMECA - PET

Zone	Equipment/Process	Requeriment	Hazardous task/activity	Hazards/aspects	Risk/impact	Heath, Safety, Environmental	Frequency	Severity	Probability	Detectability	Risk Factor	Significant	Hierachy of control
PET	Blow moulder	heat bottle preform	Change hot modules	contact with hot surface	body burn	S	2	3	4	4	96	C	Administrative controls and PPE
		blow preforms	Change bottle molders	repetitive and heavy load	arms and back pain	S	4	3	5	2	120	C	Engineering controls
		cool down preform	Adjust/remove clamps	kinetic energy	cutting	S	2	3	3	1	18	P2	Training
		send bottles to filler	Adjust clamps' wheel	kinetic energy	cutting and entaglement	S	2	4	2	1	16	P2	Training
	bottle filler	Fill up bottles	adjust the hummers	work at height	fall	S	2	2	3	2	24	P2	Administrative controls
			adjust feed caper	work at height	fall	S	2	2	3	2	24	P2	Administrative controls
			Lubrifiction	work at height and position	back pain and fall	S	3	4	4	3	144	C	Engineering controls
			change bearing	ergonomics	back pain	S	2	3	3	2	36	P2	Training
	bottle capper	Put capers in bottles	Adjust hummer	work at height	fall	S	2	2	2	2	16	P2	Administrative controls
			Change caper's guide	work at height	fall	S	2	2	2	2	16	P2	Administrative controls
	Conveyors	Drive bottles across the sections	Adjust conveyor	ergonomics	back pain position to adjust conveyor	S	3	3	2	3	54	C	Engineering controls
			Change bearing and pully	hard access to the bearing	muscles pain	S	3	3	3	3	81	C	Administrative controls
	FBI	Inspect full bottles	Adjust hummer	work in tight space	entanglement	S	2	3	3	3	54	C	Administrative controls
			adjust/remove sensors	Electrical shock	Injury , lost of life and LTI due to electrical shock by contacting with live equipments	S	2	5	4	3	120	C	Administrative controls and PPE
	bottle laber	put labers on bottles	adjust/change blades	very sharped blades	finger cutting	S	2	4	4	3	96	C	Administrative controls
			remove stack bottles in ovens	hot spots	skin burn due to contact with hot material	S	2	4	4	1	32	P2	Administrative controls
			add glue to hot container	hot glue	skin burn due to contact with hot glue	S	4	4	5	2	160	C	Administrative controls
			Remove stacked labers	ergonomics	back pain caused by the vacuum cylinder removal	S	2	4	3	2	48	P2	Administrative controls
	Date coder	put data and code in bottles	adjust laser jet sort electric cables	eletrocussion	Injury , lost of life and LTI due to electrical shock by contacting with live equipments	S	3	5	3	3	135	C	Administrative controls and PPE
	Variopac shrink-wrapper	Sort bottles Cut films	adust/change blades	very sharped blades	cutting on blades handlling	S	2	5	3	3	90	C	Administrative controls
		smooth burning of film on bottles	Change guides of bottle feed	ergonomics	wrong posture and tight space for movements	S	5	4	3	2	120	C	Administrative controls
			Climbing	work at height	fall from adjusting the feed guides	S	4	3	3	2	72	C	Administrative controls
	Robobox	Organize packing	Change motors, sensors and sort cables	eletrocussion	Injury , lost of life and LTI due to electrical shock by contacting with live equipments	S	2	5	4	4	160	C	Administrative controls and PPE
	Robopack	Packing and organizing the pallets	replace arm components	ergonomics	back pain due to work position	S	1	3	3	2	18	P2	Administrative controls
			sort electric cables	eletrocussion	Injury , lost of life and LTI due to electrical shock by contacting with live equipments	S	2	5	3	3	90	C	Administrative controls and PPE
	Palletizer	Feed pallets	Lubrifiction	ergonomics	arms pain due to work position	S	2	2	4	3	48	P2	Engineering controls
			Change chain	work at height	falls due to wrong posture	S	1	3	3	3	27	P2	Administrative controls
	shrink-wrapper	Wrap the bottles	change bearings	ergonomics	back pain due to work position	S	2	3	3	2	36	P2	Administrative controls
			Replace cutting ware	ergonomics	back pain due to work position	S	2	3	2	2	24	P2	Administrative controls
			Change rollers	ergonomics	back pain due to work position	S	2	3	3	2	36	P2	Administrative controls

APPENDIX C: Agents of hazards

Condition	Hazard
Movement of rotation	➢ Entanglement (rotating parts with/without projections) ➢ Nipping/drawing-in (gears, nips of in-running rolls, chains, belts) ➢ Shear (sliding parts, spoked wheels, mowing machine blades, dough mixer blades) ➢ Cutting (rotary knives, abrasive wheels, bacon slicers, circular saws
Linear sliding	➢ Trapping, crushing (closing platens, feed tables and fixed structures) ➢ Shear (between adjacent machine parts, guillotines) ➢ Puncture (nail guns, wire stitching, stapling, sewing needles) ➢ impact
Abrasives	➢ friction burns (rotating drums and cylinders) ➢ Abrasions (abrasive wheels, linishers)
Ejection	➢ Material (grinding debris, leaking steam, air, hydraulic oils, dusts and fumes) ➢ Components (process material, components in manufacture) ➢ Machine parts (overload failure, excessive speed, jam up, broken parts)
Stored energy	➢ Air, steam or gas under pressure (pressure storage vessels and operating cylinders) ➢ Springs (actuating cylinders, robots, machining centres) ➢ Sudden release (relief valves, vessel or pipe failure) ➢ Electrical (short circuits, discharge from capacitors, static discharge) ➢ Weights and heavy parts in an elevated position (counterweights, lift cages)
Sharp edges	➢ Shock (exposed conductors, insulation failure, no earth connection) ➢ Short circuit (fires, explosions, arc eye, burns) ➢ Overload (fires, burns)
Substances	➢ Ejection from machine (leaking seals and joints) ➢ Escape (hazardous material, high pressure steam and air, flammable gases and liquids
Radiations	➢ Ionizing (non-destructive testing (NDT), X-rays, sterilizing, nuclear) ➢ Non-ionizing (ultraviolet, infrared, lasers, radio frequency, induction heating)
Physical agents	➢ Noise (drumming panels, metal-to-metal contacts, transformer hum) ➢ Vibration (out-of-balance shafts, percussion tools) ➢ Pressure/vacuum (tunneling, diving, working in rarefied atmospheres) ➢ Temperature (high-drying ovens, heat treatment, and low-cold storage) ➢ Asphyxiation (confined spaces, exhaust fumes, gas leakages) ➢ Suffocation (by granular materials, powders, grain, liquids)

APPENDIX D – HAZARD / ASPECT CONTROL STRATEGY

TECHNIQUES TO REDUCE THE RISK

In planning to control hazards/aspect we shall consider action in accordance with the hierarchy of control listed below. This approach shall be adopted even if all specific legislative requirements have been complied with as legislation generally sets minimum standards.

A. **Engineering Controls**
   - ✓ **Elimination** – Can the hazard be removed completely? This is the most effective method.
   - ✓ **Substitution** – Is there a safer alternative? E.g. solvent with a higher flash point, a substance which is "harmful" to replace one which is "very toxic".
   - ✓ **Reduction** – Can the risk be reduced at source? E.g. machine with a lower noise level, low voltage tools. This method relies upon the reduction of risk within the organization by the implementation of a loss control program. The basic goal of such a program is to protect the organization's assets from wastage cause by accidental and other controllable loss. The above methods deal with the hazard itself and are therefore more effective than the following measures, which does nothing with the hazard other than try to control it.
   - ✓ **Enclosure** – Can the hazard be enclosed or contained?

B. **Administrative Controls**
   - ✓ **Remove person** – Can people be kept away from the hazard?
   - ✓ **Reduce contact / Exposure** – Can the hazard be diluted or time of contact or quantity be reduced?
   - ✓ **Risk Communication**
     - Instructions
     - Training
     - Supervision to appropriate level
     - Organization
     - Permits to Work
     - Emergency procedures must be prepared in the event of failure

C. **Personal Protection**
   - ✓ **Personal Protection** – Can be something be provided to the person to lessen the injury effect of accidents or try to make the person aware of the hazard? The personal protection method on its own is the least effective means of controlling hazards and must be considered as a last resort.

D. <u>TRAINING:</u>

- ✓ KORE /EOSH Coordinator, Head of Departments and Project Managers shall be trained on document requirements and the importance of its application as per Training procedure: DOC.NO. G-PR-04

E. <u>CORRECTIVE ACTION:</u>

- ✓ Apply Corrective Action Procedure, Doc No. G.PR.06 in event of ineffectiveness or non-compliances in the implementation of risk control and management.

Annex F: Criteria

	CRITERIA	Score
Severity (A)	**Catastrophic** i.e. fatality or long term impact to critical media like drinking water source, loss of property, legal requirement Toxic release off-site with long-term detrimental effects. Huge financial loss, long plant shut down	**5**
	Major long term injury or health effect or Permanent disability, long term impact to non-critical media, Off-site release with no long-term effects or impact; near sensitive environment or sensitive receiving environment, Legislation Major financial loss, time-bound shut down	**4**
	Moderate Injury Lost time injury/illness On-site release contained, Medium financial loss: (<3days off) short term impact to environment, Interruption of normal operation	**3**
	Minor Injury/illness (1day off) or minor on site impact., interruption within plant, can be contained within plant , Minor spillage contained in immediate vicinity, Low financial loss:	**2**
	Insignificant No injury, no impact a precursor situation	**1**

Frequency (B)	Constant, happens as often	**5**
	Frequent, intermittently occurs	**4**
	Occasional, once in an undefinable pattern of period	**3**
	Rare, hardly occurred	**2**
	No past occurrence, not likely	**1**
Detectability (C)	Not detectable	**5**
	Hardly detectable	**4**
	Detectable	**3**
	Observable	**2**
	Easily observable	**1**
Likelihood/ Probability (D)	**Constant/Almost certain** – It is expected to occur in all circumstances	**5**
	Likely and probable- It is expected to occur in most circumstances	**4**
	Possible – It will probably occur in most circumstances or Might occur at some time	**3**
	Unlikely and remote - It could occur at some time, but less possible	**2**
	Rare, unlikely and improbable - It may occur only in exceptional circumstances	**1**
Overall Risk Factor (RF) =A x B x C x D		

APPENDIX E - hazard/aspect identification

	HAZARD/ASPECT IDENTIFICATION	Hazard/Aspect Yes/No?
A.	**ENTANGLEMENT**	
1	Can anyone's hair, clothing, gloves, neck-tie, jewelry, cleaning brushes, rags or other materials become entangled with moving parts of the plant, or materials in motion?	No
B.	**CRUSHING**	
1	Can anyone be crushed due to:	
a.	Material falling off the plant?	**No**
b.	Uncontrolled or unexpected movement of the plant or its load?	**No**
c.	Lack of capacity for the plant to be slowed, stopped or immobilized?	**No**
d.	The plant tipping or rolling over?	**No**
e.	Parts of the plant collapsing	**Yes**
f.	Coming in contact with moving parts of the plant during testing, inspection, operation, maintenance, cleaning or repair?	**Yes**
g.	Being thrown off or under the plant?	**No**
h.	Being trapped between the plant and materials or fixed structures?	**No**
i.	Other factors not mentioned?	**N /A**
C.	**CUTTING, STABBING & PUNCTURING**	
1	Can anyone be cut, stabbed or punctured due to:	

a.	Coming in contact with sharp or flying objects?	**Yes**
b.	Coming into contact with moving parts of the plant during testing, inspection, operation, maintenance, cleaning or repair of the plant?	**Yes**
c.	The plant, parts of the plant or working pieces disintegrating?	**Yes**
d.	Work pieces being ejected?	**No**
e.	The mobility of the plant?	**No**
f.	Uncontrolled or unexpected movement of the plant?	**No**
g.	Other factors not mentioned?	**Replacements**
D.	**SHEARING**	
1	Can anyone's body parts be sheared between 2 parts of the plant, or between two parts of the plant, or between a part of the plant and a work piece or structure?	**Yes**
E.	**FRICTION**	
1	Can anyone be burnt due to contact with moving parts or surfaces of the plant?	**Yes**
F.	**STRIKING**	
1	Can anyone be stuck by moving objects due to:	
a.	Uncontrolled or unexpected movement of the plant or material handled by the plant?	**No**
b.	The plant, parts of the plant or pieces disintegrating?	**Yes**
c.	Work pieces being ejected?	**No**
d.	Mobility of the plant	**No**
e.	Other factors not mentioned?	**N/A**

G.	**HIGH PRESSURE FLUID**	
1	Can anyone come into contact with fluids under high pressure, due to plant failure or misuse of the plant?	**Yes**
H.	**ELECTRICAL**	
1	Can anyone be injured by electrical shock or burned due to:	
a.	The plant contacting live electrical conductors?	**Yes**
b.	The plant working in close proximity to electrical conductors?	**Yes**
c.	Overload of electrical circuits?	**No**
d.	Damaged or poorly maintained electrical leads & cables?	**Yes**
e.	Damaged electrical switches?	**No**
f.	Water near electrical equipment?	**No**
g.	Lack of isolation procedures?	**Yes**
h.	Other factors not mentioned?	**N/A**
I.	**EXPLOSION**	
1	Can anyone by injured by explosion of gases, vapors, liquids, dusts or other substances, triggered by the operation of the plant or by material handled by the plant?	**No**
J.	**SLIPPING, TRIPPING & FALLING**	
1	Can anyone using the plant, or in the vicinity of the plant, slip, trip or fall due to:	
a.	Uneven or slippery work surfaces?	**No**
b.	Poor housekeeping, e.g. Sward in the vicinity of the plant, spillage not cleaned up?	**No**

c.	Obstacles being placed in the vicinity of the plant?	**No**
d.	Other factors not mentioned?	**Height work**
2	Can anyone fall from a height due to:	
a.	Lack of proper work platform?	**Yes**
b.	Lack of proper stairs or ladders?	**No**
c.	Lack of guardrail or other suitable edge protection?	**Yes**
d.	Unprotected holes, penetrations or gaps?	**No**
e.	Poor floor or working surfaces, such as the lack of slip resistant surfaces?	**Yes**
f.	Steep walking surfaces?	**Yes**
g.	Collapse of the support structure?	**No**
h.	Other factors not mentioned?	**N/A**
K.	**ERGONOMIC**	
1	Can anyone be injured due to:	
a.	Poorly designed seating?	No
b.	Repetitive body movement?	Yes
c.	Constrained body posture or the need for excessive effort?	Yes
d.	Design deficiency causing mental or psychological stress?	No
e.	Inadequate or poorly placed lighting?	No
f.	Lack of consideration given to human error or human behavior?	Yes
g.	Mismatch of the plant with human traits and natural limitations?	Yes
h.	Other factors not mentioned?	N/A

L.	**SUFFOCATION**	
1	Can anyone be suffocated due to the lack of oxygen, or atmospheric contamination?	No
M.	**HIGH TEMPERATURE OR FIRE**	
1	Can anyone come into contact with objects at high temperatures?	**Yes**
N.	**TEMPERATURE (THERMAL COMFORT)**	
1	Can anyone suffer ill health due to exposure to high or low Temperature?	**Yes**
O.	**OTHER HAZARDS**	
1	Can anyone be injured or suffer ill-health from exposure due to:	
a.	Chemicals?	**Yes**
b.	Toxic gases, vapors or fumes?	**Yes**
c.	Dust?	**Yes**
P.	**OTHER HAZARDS**	
a.	Noise?	**Yes**
b.	Vibration?	**Yes**
c.	Radiation?	**No**
d.	Other factors not mentioned?	**N/A**
Q.	**ENTRAPMENT**	
1	Can anyone be locked or trapped in an area of space?	**No**
R.	**CHANGING OIL**	
a.	Air Emission- can degrade air quality	**No**

b.	Use of Oil; Absorbent – consumption of natural resources	**No**
c.	Recycling of oil- increase landfill space	**No**
d.	Spill- degrade water quality	**No**
S	**Other Aspect/Impact**	
a.	Excavation-Soil disturbance-Erosion	**No**
b.	Lighting Use – Energy Use-Use of natural resources	**No**
c.	Dust Generation – Degradation of air quality	**No**
d.	Waste generation- Decrease landfill space	**No**

APPENDIX F – Avaliação de risco

AVALIAÇÃO DE RISCO (MEIO AMBIENTE, SAÚDE E SEGURANÇA)

Moçambique - CHIMOIO

Matriz de Avaliação de Riscos

Frequência (A)	Severidade (B)	Nr de Pessoas Expostas (C)	Probabilidade de Ocorrência (D)	Valor
Nunca Ocorreu	Insignificante	1 - 2 Pessoas	Rara	1
Frequente	Menor	3 - 7 Pessoas	Nao Provavel e Remota	2
Ocasional	Moderado	8 - 15 Pessoas	Possivel	3
Raro	Maior/Fatality	16 - 50 Pessoas	Provavel e Possivel	4
Constante	Catastrofico	Mais de 50 pessoas	Constante/ quase certo	5

C	FRG >= 50	Prioridade 1	Significa que as operacoes nas condicoes actuais devem cessar ate que o risco se reduza pelo menos ao nivel de prioridade 2
P2	10 < FRG < 50	Prioridade 2	Significa que e requirida uma accao urgente para eliminar o risco ou controlar adequadamente
L	FRG =< 10	Risco Controlado ou insignificante	Significa que nao e preciso adoptar medidas metigadoras, a menos que se possa reduzir mais o risco com pouco custo ou esforco

Linha de Base/ Risco Inerente								Baseline						Controles		Residual Risk						
Zone/Area	Specific Area	Equipment /Process	Risk evaluation	Risk Activity	Hazard/Aspect	Risk/ Impact	Heath, Safety, Environmental	Frequency	Severity	Número of Exposed Person	Probability	Risk Factor	Significant	Factores para Redução do Risco	Hierachy of Control	Frequency	Severity	Number of Exposed Person	Probability	Risk Factor	Significant	SHE ACTION PLAN HIGH RISKS
CAUSTIC	Caustic recovery section	Caustic tank Pumps and caustic delivery pipes Electrical panel	Normal	Delivery of caustic	Hot surfaces	body injuru due to burn from hot pipis transporting caustic	S	1	3	1	3	9	L	HAZMAT & Handling Material	Engineering & Administration	1	3	1	3	9	L	
	Caustic recovery section	Caustic tank Pumps and caustic delivery pipes Electrical panel	Normal	discharge of caustic	Corrosive Chemical spillage	Body injury due to contact with corrosive chemical	S	1	3	1	3	9	L	HAZMAT & Handling Material	Engineering & Administration	1	3	1	3	9	L	
	Caustic recovery section	Caustic tank Pumps and caustic delivery pipes Electrical panel	Normal	discharge of caustic	Corrosive Chemical spillage	Water and soil pollution due to caustic spillage	E	1	2	4	1	8	L	Storm Water polution protetion program	Engineering & transfer	1	2	4	1	8	L	
	Caustic recovery section	Caustic Tank	Abnormal	Maintenance - Inspection and cleaning of the tank	Falling from height	Body injury, LTI due to falling from the height	S	1	4	1	1	4	L	Fall protection program	Engineering & Administration	1	4	1	1	4	L	
	Chemical dosing station for CIP	Reparacao das bombas de doseamento	Abnormal	Derramamento de quimicos	Poluicao ambiental	Poluicao de agua, solo atraves dos quimicos usados	E	1	5	5	1	25	P2	hazardous materials management	Engineering & Administration	1	5	2	1	10	L	
	Chemical dosing station for CIP	Reparacao das bombas de doseamento	Abnormal	Ensaios/Testes da bomba	Exposicao a quimicos	Queima ou irritacao da pele,vista por salpicos quimicos	H	1	5	5	1	25	P2	Procedimento de manuseio de materiais perigosos e EPI	PPE	1	5	2	1	10	L	
	Caustic recovery section	Caustic Tank	Abnormal	Maintenance - Inspection and cleaning of the tank	Work at confined spaces	Loss time injury, Lost of life, Suffocation due to inhalation of chemical and exposure for low levels of oxygen	S	1	4	1	3	12	P2	Provision of oxygen monitoring equipment. Provision of PPE's - confined space emergency tools	PPE	1	4	1	2	8	L	

Zone/Area	Specific Area	Equipment /Process	Risk evaluation	Risk Activity	Hazard/Aspect	Risk/ Impact	Heath, Safety, Environomental	Frequency	Severity	Number of Exposed Person	Probability	Risk Factor	Significant	Factores para Redução do Risco	Hierachy of Control	Frequency	Severity	Number of Exposed Person	Probability	Risk Factor	Significant	SHE ACTION PLAN HIGH RISKS
	Depalletizing	Forklift	Normal	Loading of the empties pallet	Forklift hitting the conveyor	Body Injury, fatalities, LTI and property damaging due to moviment of forklift	S	5	4	1	3	60	C	Trained forklift drivers Conveyor guards	Engineering	5	4	1	1	20	P2	
	Depalletizing	Conveyor	Normal	Conveyor movement	Entanglement, moving, stepping on the conveyor	Crushing, Severing of body parts and critical injuries, Lost time injury, lost of life due to moving conveyor	S	2	4	1	2	16	P2	Hazardous energy control procedure in place, HAZCOM in place, Trained Personnel Hazard comunications	Administration	2	4	1	1	8	L	
	Depalletizing	Depalletizer	Normal	Removing crates from the pallets to the conveyor	Entanglement of damaged crates in depalletizer, rotating and moving machine parts.	Crushing, Severing of body parts and critical injuries, Lost time injury, lost of life due to moving of Depalletizer	S	2	4	1	3	24	P2	Trained Personnel Hazard comunications Physical barriers Access control sensors Provision of emergency stop buttons	Administration	2	4	1	1	8	L	
	Depalletizing	Depalletizer	Normal	Operation & Maintenance and cleaning	Handling of Non Isolated Live equipment(power cables), Non isloated safe guards	Electrocution, LTI & body injury due to machine operation without safeguard, non isolating Live equipment	S	2	4	2	2	32	P2	Hazardous energy control procedure in place, Electrical Safety Procedure in place, HAZCOM in place, Trained Personnel	Administration	2	4	2	1	16	P2	
	Depalletizing	Depalletizer	Normal	Operation & Maintenance and cleaning	Sharing material and crowd	COVID 19 Contamination	H	4	5	4	4	320	C	Using individual Tools and provide minimum 2m physical distance from collegues	Administration	4	5	2	1	40	P2	Social distancing training, using correct PPE including the respirator mask
	Empty Conveyors	Conveyors	Normal	Transportation of crates with empty glass	Entanglement, moving, stepping on the conveyor	Crushing, Severing of body parts and critical injuries, Lost time injury, lost of life due to moving conveyor	S	2	4	1	2	16	P2	Hazardous energy control procedure in place, HAZCOM in place, Trained Personnel Hazard comunications	Administration	2	4	1	1	8	L	
	Empty Conveyors	Conveyors	Normal	Operation & Maintenance and cleaning	Crates or glass falling from the conveyor	Electrocution, LTI & body injury due to cleaning ,maintenance & non isolating Live	S	2	4	2	3	48	P2	Hazardous energy control procedure in place, Electrical Safety Procedure in place, HAZCOM in place, Trained Personnel	Administration	2	4	2	1	16	P2	
	Empty Conveyors	Conveyors	Normal	Conveyor Lubrication	Wet floor	body Injury due to falling from the conveyor lubrification process	S	2	2	3	3	36	P2	Provision of drip pans in all wet conveyor	Engineering	2	2	3	1	12	P2	
	Crate check mat	Checkmat	Normal	Removing non conforming crates with empties bottles	Hazardous energy - pneumatic	finger injury due to broken or chipneck glass	S	1	3	1	2	6	L	Hazardous Energy	Engineering	1	3	1	2	6	L	
	Uncasing area	Uncaser	Normal	Removing glass from the crates to the conveyor	Broken glass	Body injury due to broken glass	S	3	2	4	3	72	C	Physical guard Equipment maintenance , usage of appropriate ppe	Engineering	2	2	4	1	16	P2	
	Uncasing area	Uncaser	Normal	Removing glass from the crates to the conveyor	Broken glass	Waste generation due to broken glass and others waste	E	2	2	3	3	36	P2	Waste management programme in place	Administrative and transfer	2	1	3	1	6	L	
	Uncasing area	Uncaser	Normal	Operation & Maintenance	Handling of Non Isolated Live equipment(power cables)	Electrocution, LTI & body injury due to cleaning ,maintenance & non isolating Live	S	2	4	2	2	32	P2	Hazardous energy control procedure in place, Electrical Safety Procedure in place, HAZCOM in place, Trained Personnel	Administration	2	4	2	1	16	P2	
	Uncasing area	Uncaser	Normal	Cleaning	Use of detergents	Soil and water pollution due to detergent usegage	E	2	2	2	2	16	P2	Storm water program	Engineering	2	1	3	1	6	L	
	Uncasing area	Uncaser	Normal	Cleaning	Slip and fall	Body Injury due to wet area	S	2	2	5	2	40	P2	Slip resistant boots, drip puns for colleting chain lub HAZCOM	Engineering & PPE	2	2	5	1	20	P2	Provision of drip pans a must
	Crate washing area	Crate washer	Normal	Movement of personnel under the platform	Collision platform support	Head injury due to short platform	S	1	2	1	1	2	L	Fall protection & PPE	Engineering	1	2	1	1	2	L	
	Crate washing area	Crate washer	Normal	Usage of ladder to unblock crates	Fall from height	Body injury & LTI due to folling,	S	4	3	1	3	36	P2	Install fixed ladder	Engineering	4	3	1	1	12	P2	
	Crate washing area	Crate washer	Normal	Operator platform and stair case	Fall from height	Body injury & LTI due to folling,	S	1	2	1	1	2	L	Fall protection program	Engineering	1	2	1	1	2	L	
	Crate washing area	Crate washer	Normal	Crate washing	Handling of Caustic	Lung desease due to inhalation of chemical fumes	H	1	1	1	3	3	L	Handling Material & respirator program	Engineering & Administration	1	1	1	3	3	L	
	Crate washing area	Crate washer	Normal	Crate washing	Handling of Caustic	Skin burn due to chemical handling	S	1	1	1	3	3	L	Handling Material & respirator program	Engineering & PPE	2	1	1	1	2	L	
	Crate washing area	Crate washer	Normal	Crate washing	Water Usage	Depleting natural resource due to usage of water	E	2	3	1	3	18	P2	Water minimization program and Preventive maintenance program	Engineering	2	3	1	1	6	L	
	Crate washing area	Crate washer	Normal	Crate washer Cleaning	Waste genaration	Land degradation due to waste generated	E	2	2	2	2	16	P2	Waste management program	Administration & transfer	2	1	2	2	8	L	
	Crate washing area	Crate washer	Normal	Crate washer Cleaning	Glass Fragments	Glass cuts due to handling glass fragmante	S	3	2	1	2	12	P2	Use of PPE and trained personnel	Administrative & Transfer	3	2	1	1	6	L	
	Crate washing area	Crate washer	Normal	Crate washer operation	Entanglement, rotating and moving machine parts.	Crushing, Severing of body parts and critical injuries due to moving machine part	S	2	3	1	1	6	L	Machine guard program in place and use of appropiate PPE	Engineering	2	3	1	1	6	L	
	Crate washing area	Crate washer	Normal	Operation & Maintenance	Handling of Non Isolated Live equipment (power cables)	Electrocution due to handling non isolated equipment (Live)	S	1	4	1	3	12	P2	Hazardous energy control procedure in place, Electrical Safety Procedure in place, HAZCOM in place, Trained Personnel	Administration	1	4	1	2	8	L	
	Washer	Washer infeed	Normal	B/Washer infeed operations	Broken glass	Body injury due to fragment glass	S	3	2	1	2	12	P2	Use of PPE's - safety goggles, gloves, safety boots	PPE & Transfer	3	2	1	1	6	L	
	Washer	Washer infeed	Normal	Conveyor movement	Entanglement, rotating and moving machine parts.	Crushing, Severing of body parts due to moviment of conveyor	S	4	2	1	1	8	L	Machine guard	Engineering	4	2	1	1	8	L	
	Washer	Washer infeed	Normal	Washer operation	Steam leaks	Depletion of energy resources due to usage of gas	E	2	2	5	3	60	C	Preventive maintenance program in place and energy minimizaton usage programme in place	Engineering	2	2	5	1	20	P2	
	Washer	Washer infeed	Normal	Washer operation	Water consumption	Depletion of water resources	E	2	2	5	3	60	C	Water minimization program and Preventive maintenance program	Engineering	2	2	5	1	20	P2	
	Washer	Washer infeed	Normal	Washer operation	Exposed moving parts	Entanglement due to operation process	S	3	3	1	3	27	P2	Machine guarding procedure in place and guards are checked and maintained as per inspection and maintenace program	Engineering	3	3	1	1	9	L	
	Washer	Washer infeed	Normal	Washer operation	Noise	Hearing imparement due to exposure of noise	H	5	3	3	3	135	C	Hearing conservation programs, Noise survey in place	Administration	5	3	3	1	45	P2	Use both Earplug and Ear muff to metigate the risk
	Washer	Washer infeed	Normal	B/Washer operation	Caustic	Land degradation due to usage of chemical for washing	E	2	2	5	2	40	P2	SWPP in place	Engineering	2	1	5	1	10	L	
	Washer	Washer infeed	Normal	B/Washer operation	Hot surfaces	Burns and scalds skin due to contact with hot surface	S	2	2	1	1	4	L	Use of trained personnel & PPE HAZCOMM	PPE	2	2	1	1	4	L	
	Washer	Washer infeed	Normal	B/Washer operation	Hot water and steam leaks	Burns and scalds skin due to contact with hot surface	S	3	2	1	3	18	P2	Preventive maintenance program, Use of PPE , trained personne,IHAZCOMM	PPE	3	2	1	1	6	L	
	Washer	Washer infeed	Normal	B/Washer operation	Walking in Stairway & Platform	Trip, Slip and fall due to walk in stairway & Platform	S	2	3	2	2	24	P2	Use PPE & trained personnel Toe board available Guard rails Platfrom made of slip resistant material	PPE	2	3	2	1	12	P2	
	Washer	Washer infeed	Normal	Bottle washer inspection and maintenance	Caustic fumes	Respiratory disorder due to inhalation and exposure with caustic fumes	H	2	3	2	2	24	P2	Used of trained personnel, PPE and Maintenance procedures in place	PPE	2	3	2	1	12	P2	
	Washer	Washer infeed	Normal	Cleaning of the bottle washer	Caustic	Burns skin due to contact with caustic	H	1	3	2	1	6	L	Use of PPE, Confined space entry procedures and Hazardous materials management program	PPE	1	3	2	1	6	L	
	Washer	Washer infeed	Normal	Cleaning of the bottle washer	Glass Fragments	Body injury due to Glass cuts	H	3	2	1	3	18	P2	Flushing off washer before entry, use of PPE, trained personnel	PPE	3	2	1	1	6	L	
	Washer	Washer infeed	Normal	Washer cleaning	Entanglement, entranpment rotating and moving machine parts.	Crushing, Severing of body parts and critical injuries due to entanglement	S	1	4	1	3	12	P2	Hazardous energy control procedure in place, HAZCOM in place, Trained Personnel Hazmat Provision of emergency stop buttons	Administration	1	4	1	2	8	L	
	Washer	Washer Operartion	Normal	Washer discharge	Broken glass	Body injury due to handling broken glass	S	2	3	1	2	12	P2	Use of PPE's - safety goggles, safety boots	PPE	2	3	1	1	6	L	
	Washer	Washer discherge	Abnormal	Finger replacement	Entanglament, rotating and moving parts	Crushing, Severing of body parts due to movments of the rotating parts,LWD/Fatalitie	S	3	5	1	4	60	C	LOTO , SOP, WSWP Procedure	Engineering	2	4	1	1	8	L	
PRODUCTION HALL - RGB	Washer	Washer Operartion	Normal	Conveyor movement	Entanglement, rotating and moving machine parts.	Crushing, Severing of body parts due to moviment of conveyor	S	4	3	1	2	24	P2	Hazardous energy control procedure in place, HAZCOM in place, Trained Personnel Hazmat Outfeed light sensors	Administration	4	3	1	1	12	P2	
	Sighting station	Bottle inspection	Abnormal	Bottle Sighting	light from sighter screen;	Vision impairment due to prolonged exposure to high or low light intensities;	H	1	2	1	1	2	L	Rotation every 20 mins, and annual eye testing & regular monitoring of light intensity	Administration	1	2	1	1	2	L	
	Sighting station	Bottle inspection	Abnormal	Bottle Sighting	Broken glass	Body injury due to handling broken glass	S	2	3	1	2	12	P2	use of trained staff and maintenace of bottle washer	Administration	2	3	1	1	6	L	
	Sighting station	Bottle inspection	Abnormal	Bottle Sighting	Ergonomics	poor sitting habbit can lead to back pains	H	2	2	1	2	8	L	Rotation every 20 mins Properly designed chairs	Administration	2	2	1	2	8	L	
	Sighting station	Bottle inspection	Abnormal	Access to Bottle Sighting station	Moving conveyors & small space for the operation	Fall, collision with fixed conveyors leading to body injury	S	2	2	1	2	8	L	Use of ASEBI	Engineering	2	2	1	2	8	L	
	EBI	EBI	Normal	Bottle inspection	Entanglement, rotating and moving machine parts.	Crushing, Severing of body parts and critical injuries	S	1	4	2	1	8	L	Hazardous energy control procedure in place, HAZCOM in place, Trained Personnel Hazard communication Machine guards in place	Administration	1	4	2	1	8	L	
	EBI	EBI	Normal	Bottle inspection	Camera lights	Vision impairment due to intense camera light intensities	H	1	1	2	2	4	L	Tinted barriers on the equipment	Engineering	1	1	2	2	4	L	
	EBI	EBI	Normal	Bottle inspection	Broken glass	Body injury due to handling broken glass	S	2	2	1	3	12	P2	use of trained staff with proper PPE's - gloves, afety goggles and apron Covered bin for reject glass	Administration	2	2	1	2	8	L	
	Filler	Filler & Crowner	Normal	Filler Operation	Gears & moving parts	Body injury due to Entanglement of gears & moving parts	S	2	4	1	3	24	P2	Machine guards in place & Trained personnel	Engineering	2	4	1	1	8	L	
	Filler	Filler & Crowner	Normal	Bottling & Packaging	Broken glass	Land degradation due to glass disposal	E	2	2	1	2	8	L	Broken glass is sent to the supplier for recycling	Transfer	2	2	1	2	8	L	
	Filler	Filler & Crowner	Normal	Filling and Capping	Broken glass	Body injury due to handling broken glass	S	2	2	1	2	8	L	maintenance of machine guards, use of PPEs and routine cleaning of equipments	Administration	2	2	1	2	8	L	
	Filler	Filler & Crowner	Normal	Filling and Capping	Bottle bursts and bottle fragments	Body injury due to handling broken glass	S	2	2	1	2	8	L	Handling Material	Administrative	2	2	1	2	8	L	
	Filler	Filler & Crowner	Normal	Movement	Wet floor surfaces	Slip and fall leading to physical injury of associates	S	2	2	1	2	8	L	Use of Safety boots with antislip and antistatic rating	PPE	2	2	1	2	8	L	
	Filler	Filler & Crowner	Normal	Movement	Passing under conveyors	Back injury due to repetitive bending	S	2	2	1	2	8	L	Use of available crossing stair (fly overs)	Engineering	2	2	1	2	8	L	
	Filler	Filler & Crowner	Normal	Movement	Passing under conveyors	Back injuries due hitting of the back on conveyors and conveyor guides	S	2	2	1	2	8	L	Use of available crossing stair (fly overs)	Engineering	2	2	1	2	8	L	
	Filler	Filler & Crowner	Normal	Clean and sanitation	CIP Chemicals	Burning body parts by chemical contact	S	2	2	2	1	8	L	LEV provided Use of chemical resistance PPE's HAZCOMM CIP closed loop	Engineering	2	2	2	1	8	L	
	Filler	Filler & Crowner	Normal	Clean and sanitation	CIP Chemicals	Respiratory disorder due to inhalation of CIP chemical fumes	H	2	2	1	2	8	L	Respiratory protection program	Engineering & Administration	2	2	1	2	8	L	
	Filler	Filler & Crowner	Normal	Clean and sanitation	Steam & hot surfaces	Burn skin due to contact with hot surfaces	S	2	2	1	2	8	L	HOT Work program	Engineering & Administration	2	2	1	2	8	L	
	Filler	Filler & Crowner	Normal	Clean and sanitation	Steam & hot surfaces	Inhalation of steam fumes that will cause respiratory desease	H	2	2	1	2	8	L	Respiratory protection program	Engineering & PPE	2	2	1	2	8	L	
	Filler	Filler & Blender	Normal	Clean and sanitation	CIP Chemicals	Increase chemical load of the effluent	E	2	2	5	2	40	P2	Closed CIP systems, maitenance and inspection for leaks, and general tank and pipe inspections & waste water treatment plant and routine maintenance of the drainage channels.	Engineering	2	2	5	1	20	P2	
	Filler	Filler & Blender	Normal	Clean and sanitation	Water usage	Depleting natural resource due to the water consuptions	E	2	2	5	3	60	C	Water minimization program and use water gun	Engineering	2	2	5	1	20	P2	
	Filler	Date coder	Normal	Date Coding	Video jet solutions	Skin burns due to contact with soluction	S	1	2	1	2	4	L	Hazmat program	Engineering & Transfer	1	2	1	2	4	L	
	Filler	Date coder	Normal	Date Coding	Video jet solutions	respiratory illness due to inhalation of vapors	H	2	2	1	2	8	L	Respiratory protection program	Engineering & PPE	2	2	1	2	8	L	
	Filler	Date coder	Normal	Date Coding	High voltage (312 V) when changing batteries	LTI, Lost of life, desability due to Electric shock	H	2	4	1	3	24	P2	Hazardous energy control procedures, Trained electricians, Electrical safety guidelines used.	Administration	2	4	1	1	8	L	
	Filler	Date coder	Normal	Date Coding	Video jet Ink solution	Environment degradation due to spill of ink solution	E	1	2	4	3	24	P2	Small quantities held and trained personnel, spill prevention	Administration & Engineering	1	2	2	2	8	L	
	FBI	FBI	Normal	Fill height detector	Radiation	Health impact on personnel causing cancerous desease due to radiation exposure	H	2	3	1	3	18	P2	Physical barriers HAZCOMM	Engineering	2	3	1	1	6	L	
	FBI	FBI	Normal	Half & fulls glass handling	Broken glass	body injury due to handling broken glass	S	2	2	1	3	12	P2	Provision of PPE's (Gloves) Use of trained employees	PPE	2	2	1	2	8	L	
	Fulls conveyors	Conveyors	Normal	Transportation of full goods to the caser	Entanglement	Body Injury due to entanglement of conveyor in moviment	S	4	3	1	2	24	P2	Hazardous energy control procedure in place, HAZCOM in place, Trained Personnel	Engineering	4	3	1	1	12	P2	
	Fulls conveyors	Conveyors	Normal	Transportation of full goods to the caser	Crates falling from the conveyor	Personnel Injury due to folling of crates	S	3	2	1	1	6	L	Conveyor guards maintenance, HAZCOM in place, Trained Personnel and crate inspection.	Engineering	3	2	1	1	6	L	
	Fulls conveyors	Conveyors	Normal	Conveyor Lubrication	Wet floor	Body Injury, LTI due to slippery in wet floor	S	2	2	2	3	24	P2	Provision of drip pans & use of safety boots	Administration & Engineering	2	2	2	1	8	L	
	Caser area	Caser	Normal	Putting filled glass into the crates from the conveyor	Broken glass	Body injury due to broken glass folling from the crates and waste generation	S	1	2	1	2	4	L	Physical guard Equipment maintenance	Engineering	1	2	1	2	4	L	
	Caser area	Caser	Normal	Putting filled glass into the crates from the conveyor	Broken glass	glass waste generation that will degradet the land	E	2	2	2	1	8	L	Broken glass is sent to the supplier for recycling	Substituition	2	2	2	1	8	L	
	Caser area	Caser	Normal	Operation & Maintenance	Handling of Non Isolated Live equipment(power cables)	Electrocution that will cause cardiac arrest, LTI, desable, serious body injury due to handling non isolated equipment (Live)	S	4	4	1	4	64	C	Hazardous energy control procedure in place, Electrical Safety Procedure in place, HAZCOM in place, Trained Personnel, use of PPE	Administration	4	4	1	1	16	P2	
	Caser area	Caser	Normal	Cleaning	Use of detergents	Soil and water pollution due to usage of detergent	E	2	2	3	2	24	P2	SWPPP & HAZMAT in place	Engineering	2	2	2	1	8	L	
	Caser area	Caser	Normal	Cleaning	Slip and fall	Injury, LTI due to falling by slipping	S	2	2	2	3	24	P2	Slip resistant boots HAZCOM	PPE	2	2	2	1	8	L	
	Palletizing areas	Palletizer	Normal	Placing crates onto the pallets from the conveyor	Entanglement, entranpment rotating and moving machine parts.	Crushing, Severing of body parts and critical injuries due to fault of system	S	3	5	1	3	45	P2	Hazardous energy control procedure in place, HAZCOM in place, Trained Personnel Hazard communications Physical barriers Access control sensors Provision of emergency stop buttons	Administration	3	5	1	1	15	P2	
	Palletizing areas	Palletizer	Normal	Operation & Maintenance and cleaning	Handling of Non Isolated Live equipment(power cables)	Electrocution that will cause cardiac arrest, LTI, desable, serious body injury due to handling non isolated equipment (Live)	S	3	4	1	4	48	P2	Hazardous energy control procedure in place, Electrical Safety Procedure in place, HAZCOM in place, Trained Personnel	Engineering	3	4	1	2	24	P2	
	Palletizing areas	Conveyor	Normal	Conveyor movement	Entanglement, entranpment rotating and moving machine parts, stepping on the conveyor	Crushing, Severing of body parts and critical injuries due to contact with moving parts of conveyor	S	3	4	1	3	36	P2	Hazardous energy control procedure in place, HAZCOM in place, Trained Personnel Hazard communications Physical barriers Access control sensors Provision of emergency stop buttons	Engineering & Administration	3	4	1	1	12	P2	
	Palletizing areas	Forklift	Normal	Picking pallets from the conveyor	Forklift hitting the conveyor	body Injury, LTI, property damage due to impact of hitting	S	1	3	1	3	9	L	Trained forklift drivers Conveyor guards	Engineering	1	3	1	3	9	L	

Zone/Area	Specific Area	Equipment /Process	Risk evaluation	Risk Activity	Hazard/Aspect	Risk/ Impact	Heath, Safety, Environmental	Frequency	Severity	Númber of Exposed Person	Probability	Risk Factor	Significant	Factores para Redução do Risco	Hierachy of Control	Frequency	Severity	Number of Exposed Person	Probability	Risk Factor	Significant	SHE ACTION PLAN HIGH RISKS
PRODUCTION PET	PET	preform Hopper	Normal	Cleaning & Maintenace	Electrical shock	Injury , lost of life and LTI, due to electrical shock during cleaning and maintance	S	2	4	1	2	36	P2	Emergency stop, Machine safety guarding	Engineering	2	4	1	1	8	L	
	PET	preform Hopper	Normal	Forklift movement	possibilty of being hitted by fo	Injury , lost of life and LTI, due to forklift moviment	S	2	4	1	2	36	P2	Forklift operator trained, speed limit and horn	Engineering	2	4	1	1	8	L	
	PET	Countfeeder	Normal	Preform alignment & maintenance	Electrical shock	Injury , lost of life and LTI due to preform alignment and maintenance process	S	2	4	1	2	36	P2	Lock out procedure in place	Engineerng & adminstrative	2	4	1	1	8	L	
	PET	Countfeeder	Normal	Work at hight	Falling from countfeeder	Injury , lost of life and LTI due to performing work at hight	S	2	4	1	2	36	P2	Work at hight procedure	Engineering	2	4	1	1	8	L	
	PET	Countfeeder	Normal	Cleaning	Dust exposure	Ilness or lung irrittation due to exposure of dust	H	2	1	1	2	4	L	Emergency stop, Machine safety guarding, fall protection program	Engineering	2	1	1	2	4	L	
	PET	Preform heater	Normal	heating of preforms & maintenance	Hot surfaces, eletrical shock	Injury , lost of life and LTI due to electrical shock & contact with hot surface	S	3	4	1	4	48	P2	Emergency stop, Hazard communication, lock out procedure	Engineering	3	4	1	2	24	P2	
	PET	Preform heater	Normal	Working at hight	Falling	Injury , lost of life and LTI due to falling by working at hight	S	2	4	1	2	16	P2	Working at hight procedure, work permit required	Engineering	2	4	1	1	8	L	
	PET	Blower	Normal	Blowing of preforms , Maintenance, work at hight , operations	Moving machine	Injury , lost of life and LTI due to entanglement in moving parts of machine	S	2	4	1	3	24	P2	Emergency stop, Hazard communication, lock out procedure	Engineering	2	4	1	1	8	L	
	PET	Blower	Normal	Blowing of preforms , Maintenance, work at hight , operations	Eletrical shock	Injury , lost of life and LTI due to contact with live equipments	S	2	4	1	2	16	P2	Emergency stop, Hazard communication, lock out procedure	Engineering	2	4	1	1	8	L	
	PET	Blower	Normal	Blowing of preforms , Maintenance, work at hight , operations	Fallingt	Injury , lost of life and LTI due to maintenance process at hight	S	2	4	1	2	16	P2	Working at hight procedure, work permit required	Engineering	2	4	1	1	8	L	
	PET	Blower	Normal	Blowing of preforms , Maintenance, work at hight , operations	Release Carbon monoxide	suffocation due to high concentration of CO in envirnoment space	H	2	4	1	2	16	P2	Forced ventilation	Engineering	1	4	1	1	8	L	
	PET	Filler	Normal	Filling, maintenace , operations	Moving machine	Injury , lost of life and LTI due to entanglement in moving parts of machine	S	2	4	1	3	24	P2	Emergency stop, Hazard communication, lock out procedure	Engineering	2	4	1	1	8	L	
	PET	Filler	Normal	Filling, maintenace , operations	Eletrical shock	Injury , lost of life and LTI due to electrical shock by contacting with live equipments	S	2	4	1	2	16	P2	Emergency stop, Hazard communication, lock out procedure	Engineering	2	4	1	1	8	L	
	PET	Filler	Normal	Filling, maintenace , operations	Hot surfaces	Injury , lost of life and LTI due to contact with hot surface	S	2	4	1	2	16	P2	Emergency stop, Hazard communication, lock out procedure	engineering	2	4	1	1	8	L	
	PET	Filler	Normal	Filling, maintenace , operations	Falling	Injury , lost of life and LTI due to falling by working at hight	S	2	4	1	2	16	P2	Working at hight procedure, work permit required	Engineering	2	4	1	1	8	L	
	PET	Nitrogen	Normal	Movement of nitrogen cylinders, Compressed gas	Nitrogen leakage ,	suffocation due to nitrogen leak	H	1	3	1	2	6	L	Comply to compressed gas program	Engineering	1	3	1	2	6	L	
	Lab	Bottle buster tester	Normal	maintenace and operation	PRT Bottle bursting	injury, LTI due to explosion from bottles	S	1	2	1	2	4	L	Machine guarding program.	Engineering	1	2	1	2	4	L	
	PET	Video ject and FBI	Normal	maintenace and operation	Radiation Exposure	illeness, lost of life due to long exposure with radiotions	H	1	4	1	2	8	L	Respiratory protection program	Engineering, Administratic	1	4	1	2	8	L	
	PET	Video ject and FBI	Normal	maintenace and operation	Electrical shock	Injury , lost of life and LTI due to electrical shock by contacting with live equipments	S	1	4	1	2	8	L	Electrical safety	Engineering	1	4	1	2	8	L	
	PET	Air buffer Tank	Normal	Maintencance	Compressed air	injury, LTI , fatalities due to explosion from air buffer tank	S	4	5	2	2	80	C	Compressor gas management	Engineering	4	5	2	1	40	P2	
	PET	Blender	Normal	Maintenace , CIP and operation	Hot surfaces ,	Injury , lost of life and LTI due to contact with hot surface & chemical	S	2	4	1	2	16	P2	Hazard communication, Use of MSDS	Administration	2	4	1	1	8	L	
	PET	Blender	Normal	Maintenace , CIP and operation	Eletrical shock	Injury , lost of life and LTI due to electrical shock by contacting with live equipments	S	2	4	1	2	16	P2	Machine safe guarding , hazard communication lock out procedure	Engineering	2	4	1	1	8	L	
	PET	Blender	Normal	Maintenace , CIP and operation	Moving machine	Injury , lost of life and LTI due to entanglement in moving parts of machine	S	2	4	1	3	24	P2	Machine safe guarding , hazard communication lock out procedure	Engineering	2	4	1	1	8	L	
	PET	Blender	Normal	Maintenace , CIP and operation	Falling	LTI, body injury due to slippering caused by wet floor	S	2	2	1	2	8	L	Fall protecton program	Engineering	2	2	1	2	8	L	
	PET	Ozonator	Normal	Operation and Maintenance	Compressed gas ,leakage of o	compreesd gas leakage Which may cause unconsciousness, lack of oxygen, suffocation	H	3	4	3	2	72	C	Comply to compressed gas program , train the peole to understand the danger of ozone an emergerncy plan in case of scape. Calibrate Ozone detetor sensor, automatic system for shutof valve, open spaces where will not concentrate the ozone due to environmental situation	Engineering & Administrat	3	4	3	1	36	P2	
	PET	PET Control Valve station	Normal	Maintenca and inspection	Co2 release	suffocation due to CO2 concentration in envirnoment space	S	2	3	2	2	24	P2	Compressor gas management	Engineering & Administrat	2	3	2	1	12	P2	
	PET	Closure hopper	Normal	Maintenace and cleaning	Moving parts	injury, LTI due to entanglement situation	S	2	4	1	2	16	P2	Guarding	Engineering	2	4	1	1	8	L	
	PET	Closure hopper	Normal	Maintenace and cleaning	Dust accumulation	Injury and illness due to dust exposition	H	2	2	1	2	8	L	GMP program compliance	Administration	2	2	1	2	8	L	
	PET	Robobox and palletizer	Normal	Maintenance and operation	operation and maintenance	Injury , lost of life and LTI due to electrical shock by contacting with live equipments	S	2	4	1	3	24	P2	Electrical safety	Engineering	2	4	1	3	24	P2	
	PET	Robobox and palletizer	Normal	Maintenance and operation	Cleaning	LTI, body injury due to slippering caused by wet floor during cleaning process	S	2	2	1	2	8	L	Fall protectio and Handling chemical	Engineering & Administrat	2	2	1	2	8	L	
	PET	Robopack	Normal	Packing and organizing the pallets	operation and maintenance	Injury , lost of life and LTI due to electrical shock by contacting with live equipments	S	2	4	1	3	24	P2	Allocate guards	Engineering	2	4	1	1	8	L	
	PET	Autofeed Robopack conveyor	Normal	Movement of palltes with full product	Pallets alignment and organizi	Injury, LTI due to aligment of pallets	S	2	2	1	2	8	L	Allocate guards	Engineering	2	2	1	2	8	L	
	PET	Flowliners	Normal	Maintenance	eletrocussion	Injury , lost of life and LTI due to electrical shock by contacting with live equipments	S	1	4	1	2	8	L	Electrical safety	Engineering	1	4	1	2	8	L	
	PET	Flowliners	Normal	Maintenance	Moving parts	Injury fatality and LTI due to entanglemet in moving parts	S	3	4	1	2	24	P2	Machine guarding	Engineering	3	4	1	1	12	P2	
	PET	PET Fixed ladders	Normal	Operation, cleaning and maintence	Falling, tripping , slipring	Injury LTI due to falling by tripping in fixed ladder	S	3	3	1	2	18	P2	Handrials toe boards, fall protection program	Engineering	3	3	1	1	9	L	
	PET	Potable ladders	Normal	Operation, cleaning and maintence	Falling, tripping , slipring	Injury LTI due to portable by tripping in fixed ladder	S	3	3	1	2	18	P2	Fall protection program	Engineering	3	3	1	1	9	L	
	PET	Chain lub dosing stations	Normal	Mantenace, changing of drums	slipring	Injury LTI due to wet area station	S	2	2	1	2	8	L	Fall protection	Engineering & Administrat	2	2	1	2	8	L	
	PET	PET Motors	Normal	Maintenace, cleaning and operations	entanglent and eletrocussion	Injury LTI & fatality due to entanglement, electrocution by contactin with live component and moving parts	S	2	4	1	2	16	P2	Machine guard & Electrical safety	Engineering	2	4	1	1	8	L	
	PET	PET Control Painels	Normal	Maintenance	Eletrocussion	Injury , lost of life and LTI due to electrical shock by contacting with livecomponents	S	1	4	1	2	8	L	Electrical safety & Hazardous Energy	Engineering	1	4	1	2	8	L	
	PET	PET Dries	Normal	Maintenace, cleaning and operations	Eletrocussion	Injury , lost of life and LTI due to electrical shock by contacting with livecomponents	S	1	4	1	2	8	L	Electrical safety	Engineering	1	4	1	2	8	L	
	PET	Labeller	Normal	Maintenace, cleaning and operations	Eletrocussion	Injury , lost of life and LTI due to electrical shock by contacting with livecomponents	S	1	4	1	2	8	L	Allocate guards where missing	Engineering	1	4	1	2	8	L	
	PET	Shrink wrapper	Normal	Maintenace, cleaning and operations	Eletrocussios	Injury , lost of life and LTI due to electrical shock by contacting with livecomponents	S	1	4	1	2	8	L	Machine guarding & Emmergency stops	Engineering	1	4	1	2	8	L	
	PET	Sleevematic	Normal	Maintenace, cleaning and operations	Eletrocussion	Injury , lost of life and LTI due to electrical shock by contacting with livecomponents	S	1	4	1	2	8	L	Machine guarding & Emmergency stops	Engineering	1	4	1	2	8	L	

Zone/Area	Specific Area	Equipment /Process	Risk evaluation	Risk Activity	Hazard/Aspect	Risk/ Impact	Heath, Safety, Environmental	Frequency	Severity	Number of Exposed Person	Probability	Risk Factor	Significant	Factores para Redução do Risco	Hierachy of Control	Frequency	Severity	Number of Exposed Person	Probability	Risk Factor	Significant	SHE ACTION PLAN HIGH RISKS
Bridge	Bridge-Eletrical painel	Electrical Painel(PLC)	Abnormal	Operation & Maintenance	Handling of Non Isolated Live equipment(power cables)	Electrocution which can cause body injury, LTI and lost of life	S	3	4	2	3	72	C	Hazardous energy control procedure in place, Electrical Safety Procedure in place, HAZCOM in place, Trained Personnel	Engineering	3	4	2	2	48	P2	
	Bridge-Cables	Cables	Normal	Power and network line	Electrocution	Loss of life, lost time injury due to electrocution	S	1	3	1	1	3	L	Electrical safety procedures, trained electricians on site	Engineering	1	3	1	1	3	L	
	Bridge-Steam	Steam piping	Normal	Steam transportation	Burn	Body Injury, LTI due to contact with steam pipe transportation	S	2	4	1	3	24	P2	Energy minimization program in place; colour codes in the pipes; use of PPE	Engineeering	2	4	1	2	16	P2	
	Bridge-Water pipe	Water pipe	Normal	Water transportation	Water leakage	Depleting natural resource due to leakage of water on the pipe	E	2	2	1	3	12	P2	WUR Programm	Administration & Engineering	2	2	1	2	8	L	
	Bridge-Water pipe	Water pipe	Normal	Walking/working on the bridge	Objects falling over the open sides onto people or equipment below	Body Injury, LTI due to object falling over the open sides	S	2	2	1	3	12	P2	Provision of Toe board Trained personnel provision of PPE's Load rating and certification by a competent engineer Maintenance program in place	Engineering	2	2	1	2	8	L	
	Bridge-Water pipe	Water pipe	Normal	Operation & Maintenance	Bridge colapsing	Body injury, LTI, lost of life, lost of propety due to bridge collapsing	S	3	5	1	4	60	C	Provision of PPE's Load rating and certification by a competent engineer Maintenance program in place	Engineering	3	5	1	2	30	P2	
	Bridge-Water pipe	Electric panels	Abnormal	Operation & Maintenance	Handling of Non Isolated Live equipment(power cables)	Electrocution which can cause body injury, LTI and lost of life	S	2	4	1	3	24	P2	Hazardous energy control procedure in place, Electrical Safety Procedure in place, HAZCOM in place, Trained Personnel	Engineering	2	4	1	2	16	P2	
ELECTRICITY	E L& P room	Transformer room	Abnormal	Personnel accessing transformer room without authorisation	Electrocution	Loss of life, lost time injury due to electrocution	S	3	4	1	5	60	C	Room kept locked, Permit required for accessing the area	Administration	3	4	1	2	24	P2	
	E L& P room	Transformer room	Abnormal	Personnel accessing transformer room without authorisation	Sabotage	negative impact on Image of company	S	1	2	2	2	8	L	Room kept locked	Administration	1	2	2	1	4	L	
	DB	Electrical DB	Abnormal	Unauthorised access to the DB	Risk of electrical shock	Loss of life, lost time injury due to electrocution	S	3	4	1	5	60	C	Technicina trained, Use of PPE, Electrical safety procedures	Administration	3	4	1	2	24	P2	
	Comms Room	Comms Room	Abnormal	Personnel accessing transformer room without authorisation	Sabotage to system	Sabotage to system due to lack of controll which can cause damages	S	1	3	1	3	9	L	Room kept locked	Administration	1	3	1	3	9	L	
	High Voltage area	Electrical panels	Abnormal	Annual Transformer service(Grounding testing and transformer Oil regeneration by Volex Contractors	Oil Spills	Pollution of storm water and overloading of effluent system	E	2	2	2	2	16	P2	Storm water protection	Engineering and Transfer	2	2	2	1	8	L	
	High Voltage area	Electrical panels	Normal	Transformer operation	Transformer oil	Body burn due to fire caused by flammable oil which can ignite due to short circuit which can cause spark	S	3	2	1	3	18	P2	Good maintenance practices, housekeeping procedures, Spill drill awareness, fire protection	Administration	3	2	1	2	12	P2	
	High Voltage area	Electrical panels	Normal	Repairs and maintenance of Lights	Live components	Electric shock can lead to serious injury or death	S	3	4	1	5	60	C	Power isolation circuit breakers,emergency switches and Lock out/Tag out procedure in place and work precautions taken, use of PPE	Administration	3	4	1	2	24	P2	
	High Voltage area	Electrical panels	Normal	Replacement of Aged/ worn accessories/units and tightening of contacts.	Live components	Electric shock can lead to serious injury or death	S	3	4	1	5	60	C	Power isolation circuit breakers,emergency switches and Lock out/Tag out procedure in place and work precautions taken, use of PPE	Administration	3	4	1	2	24	P2	
	High Voltage area	Electrical panels	Normal	Weekly service(Cleaning of panel parts and capacitor)	Electricity	Posibility of Fire out break arising from loose contacts and short circuits which can cause body injury, LTI, fatalities due to short circuits	H	3	4	1	5	60	C	Electrical safety procedures, trained electricians, Fire fighting equipment are in place and work precautions taken	Administration	3	4	1	2	24	P2	
	High Voltage area	Electrical panels	Normal	Weekly service(Cleaning of panel parts and capacitor)	Live components	Electric shock can lead to serious injury or death	H	3	4	1	5	60	C	Power isolation circuit breakers,emergency switches and Lock out/Tag out procedure in place and work precautions taken	Administration	3	4	1	2	24	P2	
	Power rooms	Electrical panels	Normal	Electrical panel work	Live wires and components inside panel	Electrical fire from the panel and electric shock which can cause dath, LTI, Body injury	H	3	4	1	5	60	C	Access by trained and certified electricians, Electrical safety procedure, Locking of panels to avoid unauthorised access	Administration	3	4	1	2	24	P2	
	Power rooms	Electrical panels	Normal	Painting of the wall and fixing cables in the tranckings	Work at height	Fall from height leading to serious injury	S	3	3	1	3	27	P2	Work at height permit procedure, use of safe feet ladders or scaffolds, contractor management procedure	Administration	3	3	1	1	9	L	
WATER SUPPLY SYSTEM	Utilities supplies Bridge from water treatment to zone 3 corridor .	Personnel movement	Normal	Walking/working on the bridge	Slip and fall	Body injury, LTI due to walking or working on the mezzanine floor	S	3	2	1	3	18	P2	Hand rails and guards Toe Board Platform surface made of slip resistant material HAZCOMM	Engineering	3	2	1	1	6	L	
	Bridge	Personnel movement	Normal	Walking/working on the bridge	Objects falling over the open sides onto people or equipment below	Body injury, LTI, due to stap the stair	S	3	2	1	3	18	P2	Provision of Toe board Trained personnel provision of PPE's Load rating and certification by a competent engineer Maintenance program in place	Engineering	3	2	1	1	6	L	
	Bridge	Personnel movement	Normal	Walking/working on the bridge	Bridge colapsing	Body injury, LTI, Fatalities due to walking and working on bridge	S	3	4	1	5	60	C	Provision of PPE's Load rating and certification by a competent engineer Maintenance program in place	PPE	3	4	1	2	24	P2	
	Bridge	Personnel movement	Normal	Using the access fixed ladder to the platform	Fall	Body injury, LTI due to movement of people on the fix ladder	S	2	3	1	2	12	P2	Hazard communication No access control	Administration	2	3	1	1	6	L	
	Raw water and semi treated water reservior area	Water reservior	Normal	Storage of water in tanks	Tank burst ,hazardous energy	Loss of life , injury ,property loss due to explosion of storage tank	S	2	5	4	2	80	C	Engeering standards and tanks integrity certification. Maintenance program in place	Administration	2	5	4	1	40	P2	
	Raw water and semi treated water reservior area	Pipes	Normal	Water piping	Collision or hitting the pipes , ergonomics, fall, trip	Body injury due to the collisions, tripping and falling	S	2	2	1	2	8	L	Hazard communication	Administration	2	2	1	2	8	L	
	Row Water and semi-treated Water	Storage tank and pipes	Normal	Water storage and piping	Water leak	Depleting natural resource due to usage of water	E	2	2	3	2	24	P2	Water usage ration program	Engineering & Administration	2	2	3	1	12	P2	
	Water Treatment	Pumps	Normal	Water pumping	Energy usage	Depleting natural resources due to usage of electricity	E	2	2	3	2	24	P2	Energy usage reduction initiatives	Administration & Engineering	2	2	2	1	8	L	
	Water Treatment	Tanks & roofs	Normal	Operation and maintenance	Work at height	Body injury; LTI, due to Falling at hight	S	2	3	1	3	18	P2	Fall protection procedure Provision of fixed ladders with a cage surrounding the climbing side of the ladder with landing platform, access control. No chains for access control	Administration	2	3	1	2	12	P2	
	Water Treatment	Panels	Normal	Operation and maintenance	Live wires and components inside panel	Body injury, LTI due to fire from the panel and electric shock	S	2	3	1	3	18	P2	Access by trained and certified electricians, Electrical safety procedure, Locking of panels to avoid unauthorised access	Administration	2	3	1	2	12	P2	
	Water Treatment	Chemical storage	Normal	Storage of chemicals	Contact with Chemicals	Chemical burns skin due to accident contact with chemical	S	2	2	1	3	12	P2	Safety showers and eye washes, use of gloves and use of MSDS. Spill Kit	Administration	2	2	1	2	8	L	
	Water Treatment	Chemical storage	Normal	Storage of chemicals	Chemicals spill	Soil and water pollution due to usage of chemical	E	2	2	3	2	24	P2	Hazmat program	Administration & Engineering	2	2	2	1	8	L	
	Water Treatment	Chemical storage	Normal	Storage of chemicals	Chemicals dust & fumes	Inhalation of chemicals which can cause respiratory illness and lung disease	H	2	3	1	3	18	P2	Oprovision of LEV's & use of PPE	Administration	2	3	1	1	6	L	
	Water Treatment	Chemical storage	Normal	Issuing of chemicals	Contact with Chemicals	Chemical burns skin due to accident contact with chemical	S	2	2	1	3	12	P2	Safety showers and eye washes, use of gloves and face shield, apron and MSDS available.	Administration	2	2	1	2	8	L	
	Water Treatment	Chemical storage	Normal	Issuing of chemicals	Chemicals spill	soil and water pollution due to uncontrolled and unsecure usege of chemical	E	2	2	3	2	24	P2	Hazmat program	Administration & Engineering	2	2	2	1	8	L	
	Water Treatment	Chemical storage	Normal	Issuing of chemicals	Chemicals dust & fumes	Inhalation of chemicals which can cause respiratory illness and lung disease	H	2	3	1	3	18	P2	Oprovision of LEV's & use of PPE	Administration	2	3	1	2	12	P2	
	Water Treatment	Water treatment	Normal	Repairs and maintenance of Lights	Working at height	Body injury, LTI due to Falling off from a height	S	3	3	1	3	27	P2	Work at height permit procedure, use of safe feet ladders or scaffolds, contractor management procedure	Administration	3	3	1	2	18	P2	
	Water Treatment	Dosing station	Normal	Preparation and dosing of chemicals	Chemicals fumes and dust	Inhalation of chemical vapours, dust, fumes which can cause respiratory illness and lung desease	H	2	3	1	3	18	P2	Oprovision of LEV's & use of PPE	Administration	2	3	1	2	12	P2	
	Water Treatment	Dosing station	Normal	Preparation and dosing of chemicals	Chemicals contant	Chemical burns skin due to accident contact with chemical	S	2	2	1	3	12	P2	Safety showers and eye washes, use of gloves and face shield, apron and MSDS available.	Administration	2	2	1	2	8	L	
	Water Treatment	Dosing station	Normal	Preparation and dosing of chemicals	Plastic & Polythene bags	Soil Degradation due to exposing with non degradation waste	E	2	2	3	2	24	P2	Solid waste being managed as per solid waste program	Administration & transfer	2	2	2	1	8	L	
	Water Treatment	Dosing station	Normal	Hiiting of the plastic pipes delivering chemicals to dosing points	Chemicals spill	soil and water pollution due to uncontrolled and unsecure usege of chemical	E	2	2	3	2	24	P2	SWPPP in place , Hazard communication	Administration & Engineering	2	2	2	1	8	L	
	Water Treatment	Dosing station	Normal	Hiiting of the plastic pipes delivering chemicals to dosing points	Chemicals spill	Chemical burns skin due to accident contact with chemical	S	2	2	1	3	12	P2	Safety showers and eye washes, use of gloves and face shield, apron and MSDS available.	Administration	2	2	1	2	8	L	
	Water Treatment	Water Treatment	Normal	Sand filters, carbon purifiers, raw water tanks, semitreated water tanks. Treated water, recovery tanks, RO treated water tanks maintenance activities	Confined spaces (Tanks, clarifier, filters)	Loss time injury, Lost of life, Suffocation due to inhalation of chemical and exposure for low levels of oxygen	S	3	4	1	5	60	C	Aeration of evaporator by openning all manholes, air tests before entry, whistles for communication, confined space procedures applied; Hazard comunications	Administration	3	4	1	2	24	P2	
	Water Treatment	Pumps	Normal	Water treatment	Energy consumption	Depleting natural resources due to usage of electricity	E	2	2	3	2	24	P2	EUR Project	Engineering & Administration	2	2	2	1	8	L	
	Water Treatment	Filters	Normal	Access to sand, carbon filter, tanks in the water treatment	Elevated platform	Body injury, LTI due to slipping and falling off from a height	S	2	3	1	3	18	P2	Guard Rails in place, toe board provided, use of anti slip safety shoes and use of the Helmet when getting up. Platform made of anti slip material	Administration	2	3	1	1	6	L	
	Row Water and semi-treated Water	Row Water and semi-treated Water	Normal	Water supply	Water usage	Depleting natural resource due to usage of water	E	2	2	3	2	24	P2	WUR Programm	Engineering & Administration	2	2	3	1	12	P2	
	Water Treatment	Recharging of Carbon and sand	Normal	Recharging of Carbon and sand	Carbon dust	Respiratory problems and lung desease due to carbon dust generated during carbon and sand recharge in filters	H	2	3	1	3	18	P2	Use of respirators (PPE)	PPE	2	3	1	1	6	L	
	Water Treatment	Recharging of Carbon and sand	Normal	Recharging of Carbon and sand	Working at height	Body injury, LTI due to Falling off from a height	S	3	3	1	3	27	P2	Work at height permit procedure, use of safe feet ladders or scaffolds, contractor management procedure	Administration	3	3	1	1	9	L	
	Water Treatment	Service of Water Treatment plant	Normal	Monthly service on the Water Treatment Plant (Megalling of motors ie winding continuity test,insulation resistance tests,winding resistance tests.)	Working at height	Body injury, LTI due to Falling off from a height	S	3	3	1	3	27	P2	Work at height permit procedure, use of safe feet ladders or scaffolds, contractor management procedure	Administration	3	3	1	1	9	L	
	Water Treatment	Chlorination	Normal	Water treatment	Chlorine fugitive emissions	Pollution of air due to emissions of fumes from chlorine	E	2	2	2	3	24	P2	Climate protection program	Engineering	2	2	2	1	8	L	
	Water Treatment	maintenance	Normal	Tank maintenance	Working at height	Body injury, LTI due to Falling off from a height	S	3	3	1	3	27	P2	Work at height permit procedure, use of safe feet ladders or scaffolds, contractor management procedure	Administration	3	3	1	2	18	P2	
	Water Treatment	pumping	Normal	Pump house and pumping	Noise Levels	Environmental nuissance to neighbouring community and employees due to high noise levels	H	3	2	2	3	36	P2	Hearing conservation programs including use of hearing protectors, audiometric testing, noise reduction improvements	Administration	3	2	2	2	24	P2	
	Water Treatment	Maintenance	Normal	Panel service and maintenance	Electricity	Posibility of Fire out break arising from loose contacts and short circuits which can cause body injury, LTI, fatalities due to short circuits	S	4	4	1	4	64	C	Power isolation circuit breakers,emergency switches and Lock out/Tag out procedure in place, use trained staff and work precautions taken	Administration	4	4	1	2	32	P2	
	Water Treatment	Sevice	Normal	Monthly service on the W.T.P(Megalling of motors ie winding continuity test,insulation resistance tests,winding resistance tests.)	Electricity	Posibility of Fire out break arising from loose contacts and short circuits which can cause body injury, LTI, fatalities due to short circuits	H	4	4	1	5	80	C	Power isolation circuit breakers,emergency switches and Lock out/Tag out procedure in place, use trained staff and work precautions taken	Administration	4	4	1	2	32	P2	
	Water Treatment	Pumping	Normal	Pump house and pumping	Electricity	Posibility of Fire out break arising from loose contacts and short circuits which can cause body injury, LTI, fatalities due to short circuits	H	4	3	1	5	60	C	Power isolation circuit breakers,emergency switches and Lock out/Tag out procedure in place, use trained staff and work precautions taken	Administration	4	3	1	2	24	P2	
	Water Treatment	carbon filter	Normal	Steaming of Carbon Purifiers	Steam	Burn skin due to contact with hot surfaces	S	3	2	1	3	18	P2	Relief valves & Regulators in place and adherance to Operating procedures and use of trained staff	Administration	3	2	1	2	12	P2	
	Water Treatment	carbon filter	Normal	Steaming of Carbon Purifiers	Hot surfaces	Burn skin due to contact with hot surfaces	S	3	2	1	3	18	P2	Lagging of steam pipes, use of PPEs and use of trained personnel	Administration	3	2	1	2	12	P2	
	Water Treatment	Chemical	Normal	Cleaning of Tanks	Chemical Residues	soil and water pollution due to uncontrolled and unsecure usege of chemical	E	2	2	3	2	24	P2	Storm water polution protetion program	Engineering	2	2	2	1	8	L	
	Water Treatment	Chemical	Normal	Cleaning of Tanks	Chemical Residues	Inhalation of chemical fumes which can cause lung disiase	H	2	3	1	3	18	P2	Use of PPEs	PPE	2	3	1	1	6	L	
	Water Treatment	Nano filters and RO unit	Normal	Chemical CIP	Contact with Chemicals	Inhalation of chemical fumes which can cause lung disiase	H	2	3	1	3	18	P2	Closed system Use of respirators, face shield, apron, chemical resistant gloves	PPE	2	3	1	1	6	L	
	Water Treatment	Nano filters and RO unit	Normal	Chemical CIP	Chemicals residues	soil and water pollution due to uncontrolled and unsecure usege of chemical	E	2	2	3	2	24	P2	SWPPP in place , Hazard communication	Engineering	2	2	2	1	8	L	
	Water Treatment	Chemical	Normal	Laboratory tests	Chemicals	Inhalation of chemical fumes which can cause lung disiase	H	2	3	1	3	18	P2	Closed system Use of respirators, face shield, apron, chemical resistant gloves	Administration	2	3	1	2	12	P2	
	Water Treatment	Chemical	Normal	Laboratory tests	Chemicals	Body burns due to contact with chemical	S	2	2	1	2	8	L	Use of trained staff and PPEs	PPE	2	2	1	2	8	L	
	Water Treatment	Chemical	Normal	Chemical Storage	Chemical Spills	soil and water pollution due to uncontrolled and unsecure usege of chemical	E	2	2	3	2	24	P2	Following the Hazardous Materials management and secondary container as well SWPP	Engineering	2	2	2	1	8	L	
	Water Treatment	Personnel movement	Normal	Walking up and down the stairs	Slip and fall	Body injury, LTI due to stap the stair	S	3	2	1	3	18	P2	Hand rails and guards Toe Board Landing platform provided Platform/stairs surface made of slip resistant material HAZCOMM	Engineering	3	2	1	2	12	P2	
	Water Treatment	Personnel movement	Normal	Walking up and down the stairs	Objects falling over the open sides onto people or equipment below	Body injury, LTI, due to stap the stair	S	3	2	1	3	18	P2	Provision of Toe board Trained personnel provision of PPE's Load rating and certification by a competent engineer Maintenance program in place	Engineering	3	2	1	2	12	P2	
	Water Treatment	Personnel movement	Normal	Walking up and down the stairs	Stairs collapsing	Body injury, LTI; fatalities due to collapsing of stair	S	4	4	2	2	64	C	Load rating and certification by a competent engineer Maintenance program in place	Administration	4	4	2	1	32	P2	
	Water Treatment	Personnel movement	Normal	Walking up and down the stairs	Slip and fall	Body injury, LTI due to stap the stair and slip	S	3	2	1	3	18	P2	Hand rails and guards Toe Board Landing platform provided Platform/stairs surface made of slip resistant material HAZCOMM	Engineering	3	2	1	1	6	L	
	Water Treatment	Personnel movement	Normal	Walking up and down the stairs	Objects falling over the open sides onto people or equipment below	Body injury, LTI, due to object folling over the opening sides	S	3	2	1	3	18	P2	Provision of Toe board Trained personnel provision of PPE's Load rating and certification by a competent engineer Maintenance program in place	Administration	3	2	1	1	6	L	
	Water Treatment	Personnel movement	Normal	Walking up and down the stairs	Stairs collapsing	Body injury, LTI; fatalities due to collapsing of stair	S	4	5	1	3	60	C	Load rating and certification by a competent engineer Maintenance program in place	Administration	4	5	1	1	20	P2	
	Water Treatment	Water Tanks Fixed ladders	Normal	Operation and maintenance	Slip and fall	Body injury, LTI due to stap and slip the fixed ladder during maintenance and operartion sprocess	S	3	2	1	3	18	P2	Fall protection procedure Provision of fixed ladders with a cage surrounding the climbing side of the ladder with landing platform, access control.	Administration	3	2	1	2	12	P2	
	Pump House	Fire engine	Normal	Fire engine operation	Battery acids	Body injury due to Chemical Acids contact	S	2	2	1	3	12	P2	Hazard communication Spill kits	Administration	2	2	1	2	8	L	
	Pump House	Fire engine	Normal	Fire engine operation	Electricity	Body injury, LTI due to Electric shock caused by livevor non isolated equipment	S	2	2	1	3	12	P2	Power isolation circuit breakers,emergency switches and Lock out/Tag out procedure in place, use trained staff and work precautions taken	Administration	2	2	1	2	8	L	
	Pump House	Fire engine	Normal	Fire engine operation	Noise Levels	Hearing impairment due to exposition of high noise area which can damage ears	H	3	2	2	3	36	P2	Hearing conservation programs Provision of PPE'e	Administration	3	2	2	1	12	P2	
	Pump House	Fire engine	Normal	Fire engine operation	Moving parts	Entrapment, entanglement, severing of body parts and possible death	S	3	3	1	3	27	P2	Machine guarding, LOTO procedure	Administration	3	3	1	1	9	L	

APPENDIX G – Ergonomic assessment

Process	Activity/ Task	Ergonomics Hazard	At-risk Body Part or Environment: Environment	Back	Shoulder	Neck	Hand/ Wrist	Whole Body	Knee	Critical; Priority 2; High;or Low	Recommende Corrective Action	Critical; Priority 2; High;or Low
Syrup Room	Concetrate Mixing	Pushing/ Pulling of trolleys		X	X					C	1. Acquire a trolley with big wheels to assit transportation of concetrates. 2. Make sure that transport routes are even, not slippery and without obstacles	Critical
		Back Posture		X						C	1. Acquire a trolley with big wheels to assit transportation of concetrates. 2. Make sure that transport routes are even, not slippery and without obstacles	Critical
		Carrying of Conc Boxes and Jerrycans		X	X					C	Acquire a trolley/pallet jack with big wheels to assit transportation of concetrates.	Critical
Line 3 & 4	Closure/ Crowns Loading in the closure/ crowns hoppers	Carrying of Closure/ Crown Boxes		X	X					C	1. Reduce the distance of carrying of boxes to the hopper. 2. Train all person involved in the activity on proper material handling techniques	Critical
		Back Posture		X						C	1. Reduce the distance of carrying of boxes to the hopper. 2. Train all person involved in the activity on proper material handling techniques	Critical
Line 3	Depalletizing	Work-related stress due a combination of bending, lifting and carrying	X							C	1. Install a load leveler at the station 2. Train personel on safe lifting techiques	Critical
		Pushing/ Pulling of Pallets		X	X					C	Use of Forklift to move pallets at the Depalletizer area	Critical
		Hand Exertion due to lifting and carrying of CFBs					X			C	Use of rubber cut resistant gloves to help reduce the force exerted directly on the fingers while lifting.	Critical
Line 3	Manual Packing at the Packing station	Work-related stress due to repititive muscle movement and high pace	X							C	1. Provide 20 Minutes breaks to the Packers every after 2 hours to allow muscles to relax 2. Provide alternative tasks to the operators to other locations that don't involve using the same muscles 3. Provide training on the station ergonomics to all Packers	Critical
		Hand Exertion due to Repeated lifting					X			C	Install a botte packing machine	Critical
Line 3	Manual Operation of the Uncaser	Work-related stress due to dust and repitition	X							C	1. Implement job rotation at the station 2. Provide dust mask to reduce exposure to dust from the bottles 3. Install uncasing machine 4. Use both uncasing units for the high speed products	Critical
		Back Posture		X						C	1. Install uncasing machine 2. Use both uncasing units for the high speed products 3. Implement job rotation at the station to allow muscle relaxation	Critical
		Shoulder Posture			X					C	1. Install uncasing machine 2. Use both uncasing units for the high speed products 3. Implement job rotation at the station to allow muscle relaxation	Critical
		Hand Exertion due to holding uncaser & Removing CFBs					X			C	1. Install uncasing machine 2. Use both uncasing units for the high speed products 3. Implement job rotation at the station to allow muscle relaxation	Critical

Process	Activity/ Task	Ergonomics Hazard	At-risk Body Part or Environment							Critical; Priority 2; High;or Low	Recommende Corrective Action	Critical; Priority 2; High;or Low
			Environment	Back	Shoulder	Neck	Hand/ Wrist	Whole Body	Knee			
Quality Laboratory PET Bench	Process Monitoring & Control	Back Posture		x						C	Change the working height (e.g. by changing the height of the work table or feeding point) so that the worker can handle the work item without bending the body.	Critical
		Shoulder Posture			x					C	1. Train the QCs on Manual handling techniques while lifting the full good crates 2. Provide a trolley for sampling of product especially 2 liter full good bottles	Critical
Line 4	Preform Loading	Pushing/ Pulling of trolley with Full Preform Box		x	x					C	1. Acquire a trolley with big wheels to assit transportation of concetrates. 2. Make sure that transport routes are even, not slippery and without obstacles	Critical
Warehousing	Product Stripping in Yard	Work-related stress due to working under the sun and combination of lifting, carrying and bending	x							C	1. Provide a product stripping shade to protect the workers from the sun UV rays. 2. Investigate the separation of bending from carrying or lifting the crates	Critical
		Shoulder Posture due to frequent movement			x					C	Acquire a product stripping machine rather than using hands	Critical
Line 4	Shrinkwrap Replacement at the Kister	Pushing/ Pulling of the Shrinkwrap Rolls		x	x					C	1. Use the availed trolley to move the the shrinwrap rolls 2. Train technicians how to use the trolleys	Critical
		Carrying of shrinkwrap Rolls		x	x					C	1. Use the availed trolley to move the the shrinwrap rolls 2. Train technicians how to use the trolleys	Critical
		Lifting of Shrinkwrap Rolls		x	x					C	1. Use the availed trolley to move the the shrinwrap rolls 2. Train technicians how to use the trolleys	Critical
		Shoulder Posture			x					C	1. Use the availed trolley to move the shrinwrap rolls 2. Train technicians how to use the trolleys	Critical
		Back Posture		x						C	1. Use the availed trolley to move the the shrinwrap rolls 2. Train technicians how to use the trolleys	Critical