International Journal of Safety and Security Engineering
Vol. 13, No. 6, December, 2023, pp. 1025-1038
Journal homepage: http://iieta.org/journals/ijsse

Qualitative Risk Assessment in Water Bottling Production: A Case Study of Maan Nestlé Pure Life Factory

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https://doi.org/10.18280/ijsse.130605

Received: 27 August 2023
Revised: 8 October 2023
Accepted: 31 October 2023
Available online: 25 December 2023

Keywords:
hazard, risk, risk matrix, QRA, risk rating

ABSTRACT

A comprehensive qualitative risk assessment (QRA) was conducted at the Maan Nestlé Pure Life factory, encompassing its production, storage, and bottling sections. Through a meticulous review of records, analysis of activities, and examination of work procedures, potential hazards within the factory were identified and subsequently categorized using the risk matrix technique. In total, seventeen hazards were identified, of which seven were deemed high risk, eight medium, and two low. This assessment underscores the imperative for measures aimed at risk control, reduction, or elimination. The QRA's qualitative approach, while effective in broad hazard identification, may have led to an incomplete hazard inventory. Nonetheless, it proved instrumental in pinpointing safety hazards and informing the development of robust safety policies. These policies integrate considerations of human behavior and equipment failure, focusing on preserving product quality while safeguarding the business and its operators. Despite the presence of an unsafe workplace, the study revealed that the need for new infrastructure is non-essential. Instead, a series of modifications are recommended, including the replacement of defective roofs, installation of electrical rolls and lifts, segregation of chemical storage, personnel training, and various ergonomic and procedural adjustments. The study further advocates for a subsequent phase of analysis utilizing quantitative techniques such as fault tree analysis. This is particularly pertinent for hazards requiring specific root cause identification, enabling the determination of necessary safety controls to address these root causes and prevent hazard occurrence.

1. INTRODUCTION

1.1 Basics and definitions

In industrial facilities, safety is a paramount concern, primarily due to the risks of workplace fatalities and injuries resulting from inadequate safety measures and the absence of robust Occupational Health and Safety Management Systems. In the Jordanian labor market, as reported by Jordan Labor Watch, occupational injuries are recorded every 25 minutes, with a work-related death occurring every two days. Estimates from the Social Security Corporation indicate approximately 20,000 work accidents annually, equating to a rate of 11.7 injuries per 1,000 individuals. The industrial sector accounts for approximately 25.3% of all work-related fatalities, with the wholesale and retail trade sector contributing to 17.7%. Furthermore, the industrial sector experiences 31.6% of total work injuries, followed by the health and social work sector at 22.0%. Notably, almost half of all occupational injuries befall workers under 30 years of age, underscoring the imperative for heightened awareness and specialized training to safeguard the health and safety of younger workers [1].

Safety, as a discipline, aims to minimize the loss of life and property attributable to accidents as much as possible [2]. Workplace incidents not only affect workers but also have adverse financial implications for employers. The costs associated with an accident can manifest in various forms, including salary expenditures, productivity losses, retraining, compensation payments, repairs, and medical expenses.

Like any industrial sector, the water bottling industry faces occupational hazards at various stages, including production, storage, and distribution. The industry predominantly employs automated processes, supplemented by some manual handling and repetitive tasks performed by workers. Consequently, this environment presents multiple workplace hazards, including ergonomic challenges, mechanical design issues, physical activity demands, chemical exposures, and psychosocial stressors. As a result, factory workers in this sector are more vulnerable to occupational morbidities and fatalities due to these heightened workplace risks.

Globally, the International Labor Organization (ILO) estimates that approximately 2.78 million individuals succumb annually to occupational diseases or job-related accidents. Furthermore, around 374 million non-fatal injuries occur each year, leading to a minimum of four days of work missed per injury. The economic implications of substandard workplace safety and health practices account for about 3.94 percent of the global gross domestic product annually [2]. Yet, the human toll of this frequent adversity is incalculable.

Risk, in this context, is the possibility or likelihood of harm resulting from exposure to a hazard. However, Kaplan and Garrick [3] describe risk as uncertainty coupled with potential damage or loss, while safety is defined as being protected from possible harm. The Society for Risk Analysis (SRA) [4] characterizes risk as "The potential for realization of unwanted, adverse consequences to human life, health, property, or the environment". Conversely, risk assessment involves the identification, analysis, and evaluation of hazards [3].

The risk assessment process is integral to occupational health and safety management plans, serving to heighten employee awareness of potential workplace hazards and risks [5]. This process is methodical and recurring, commencing with the identification of risks and risk factors capable of causing harm. It then progresses to the analysis and assessment of the risks associated with these identified hazards, culminating in the determination of appropriate measures for risk elimination or control. The selection of strategies to minimize or eradicate these risks is contingent upon the nature of the risk in question [6].

Effective risk management begins with risk assessment. When a company employs five or more individuals, conducting and documenting a risk assessment becomes a legal obligation [7]. In response to this requirement, companies often develop informative tools to facilitate risk assessments. According to HSE [8], the fundamental components of successful risk management systems include policy, organization, planning and implementation, performance measurement, and review. The techniques employed in risk assessment are pivotal in establishing priorities and setting objectives for the elimination of hazards and the reduction and control of risks in health and safety management [9].

1.2 More on the concepts

Comprehending risk assessment necessitates a clear understanding of the concepts of hazard, risk, and safety. A hazard is defined as any potential source of harm; it may pose a threat to people, organizations, or the environment. For instance, a wet floor constitutes a hazard. Hazards are diverse and can encompass physical hazards, which are factors capable of causing harm (like a spill on the floor or constant loud noise), and chemical hazards, which include harmful chemical substances in any form (such as cleaning products or asbestos) [8]. When conducting risk assessment, various methods are employed to identify hazards and assess their potential effects [3]. Statistics from social security reveal that falls constitute the most common type of work injury, accounting for 28.03 percent of total injuries. This is followed by incidents involving manual labor tools, which represent 11.9 percent of injuries, and injuries resulting from falling objects at 9.68 percent. Additionally, the data indicate that road accidents are the leading cause of injury-related deaths, responsible for 46.8 percent of total fatalities, followed by incidents involving explosions, fires, and falls [1].

Risk is defined as the likelihood of the occurrence of a harmful event and the severity of the resultant harm. For example, the risk associated with slipping on a wet floor encompasses both the probability of the slip occurring and the potential consequences of such an event [9]. The interplay between probability and consequences can significantly impact individuals' daily activities, as well as their professional and personal decision-making processes [10]. An alternate perspective on risk considers it as the probability that a hazard will adversely affect individuals, organizations, or the environment, coupled with the potential outcomes of the hazard's occurrence. A risk is deemed low when the likelihood of the event happening is minimal, and its impact is considered mild. Conversely, the risk is considered high if there is a high probability of the event occurring and the potential effects are severe. It is important to note that while a hazard is a prerequisite for risk, the presence of a hazard invariably implies some level of risk [9].

Safety involves determining whether a risk is sufficiently low to be considered safe or high enough to be deemed harmful. Safety assessments, which may vary in their conclusions, can be conducted either individually or by governmental organizations [9]. Risk assessment, therefore, is a process enabling safety teams to identify hazards, assess the likelihood and severity of hazardous events, and then determine necessary actions. As a distinct concept, risk management is a dynamic, continuous process encompassing hazard identification, analysis, mitigation measures, and response to risk factors. While risk assessment is focused on detecting hazards and analyzing all potential hazards and risks in the workplace, it is a component of risk management. Essentially, risk assessment involves hazard identification, analysis, and evaluation. The responsibility for hazard identification typically lies with managers and senior employees who possess knowledge about various workplace hazards and risks. These hazards might include fires, chemical exposures, data breaches, and other incidents capable of harming people and property. The associated risks could pertain to health, safety, or quality. Risk analysis, a crucial part of risk assessment, delves into the consequences of identified hazards and their impact on work sustainability. Following this, risk evaluation involves categorizing risks based on their severity and likelihood. To facilitate this, risks can be ranked using a risk assessment matrix.

1.3 Types of risk assessments

In any workplace, the types of risk assessments conducted should be proportionate to and aligned with the operational activities being carried out. The choice of risk assessment method depends on the frequency of occurrence and the factors that trigger the need for such assessments [7]. Generally, risk assessments can be categorized into two primary types based on these considerations [4]. The first type is the standard risk assessment, which is routinely conducted at regular intervals. This form of assessment is a foundational element of ongoing safety management, providing a consistent review of potential risks within the workplace. The second type, known as dynamic risk assessment, serves to address any gaps identified in the standard risk assessment. It is typically implemented when new hazards are introduced or identified in the workplace, ensuring that emerging risks are promptly and effectively managed [11].

Standard risk assessment encompasses five prevalent types. The first is a fire risk assessment, which systematically evaluates factors related to fire hazards, the likelihood of a fire occurring, and the potential consequences should one arise [12]. Manual handling assessments are crucial in sectors like healthcare, agriculture, manufacturing, and construction, recognized for high-risk manual handling activities due to their frequency and nature. Display Screen Equipment (DSE) assessments are required in workplaces where employees use computers, LCDs, etc. [5], and are also applicable to tablets, smartphones, and laptops [7]. COSHH (Control of Substances Hazardous to Health) assessments focus on hazards and risks from hazardous substances in the workplace. Lastly, complex risk assessments are necessary for larger-scale systems, such as nuclear power plants or meteorological systems, which involve intricate interactions between mechanical, electronic, nuclear, and human elements [11]. In contrast, dynamic risk assessment is utilized to address any gaps left by standard risk assessments or in response to the introduction of new hazards in the workplace [11]. Dynamic risk assessment involves analyzing workplace risks and hazards and implementing controls to reduce or eliminate them. However, sudden changes in the work environment, such as the introduction of new hazards, necessitate this form of assessment [12]. Dynamic Risk Assessments enable safety professionals to quickly evaluate risks in changing environments, ensuring continued safe work practices. While standard risk assessments are prepared in advance, recorded, and regularly monitored, dynamic risk assessments are conducted on the spot by individuals as they encounter new environments or changes within them.

Furthermore, the implementation of a dynamic risk assessment does not negate the necessity for a standard risk assessment. Rather, the dynamic risk assessment serves as a complement to the standard risk assessment, addressing any unforeseen gaps or nuances that the latter may not have anticipated [11]. It is incumbent upon those responsible for safety to conduct a dynamic risk assessment prior to encountering any new situation or environment. Essentially, as circumstances evolve, it is imperative for the safety team to continually reassess risks and hazards, adapting their approach to ensure the utmost safety and hazard mitigation.

1.4 The implementation of risk assessment

The risk assessment process is designed to evaluate the likelihood and severity of potential harm. This process encompasses five sub-processes: hazard identification, risk analysis, risk evaluation, risk control, and assessment review, with the provision for reassessment if necessary. Hazard identification involves scrutinizing processes and work procedures to identify conditions that could potentially harm people. In the stages of risk analysis and risk evaluation, assessors determine the probability of each hazard occurring and the severity of its potential consequences. Risk evaluation also facilitates the ranking of hazards based on their risk ratings. Risk control, on the other hand, focuses on identifying measures to eliminate hazards, either by preventing their occurrence or, if that is not feasible, by controlling the risk. This stage includes documenting the findings of the assessment. The final stage involves revising control plans, making improvements, and implementing administrative actions to ensure a healthy and safe working environment [6]. The ISO-IEC 31010:2019 standard outlines the steps involved in hazard identification and risk assessment. Published as a dual-logo standard with ISO, it offers guidance on the selection and application of various techniques for assessing risk in diverse situations. These techniques aid decision-making in scenarios with uncertainty, provide insights about specific risks, and are part of a broader risk management process. The standard provides a framework for organizations to identify, assess, and manage risk, applying to various contexts and industries. It aims to assist organizations in making informed decisions about risk management and in developing risk management strategies tailored to their unique needs and circumstances [12].

Several categories of risk evaluation methods exist to estimate individual components of risk accurately, aiming to reflect reality more effectively. These categories include qualitative, quantitative, and semi-quantitative risk assessments. The choice among these types depends on the specific circumstances and the availability of data. In certain situations, it is feasible to implement more than one type of assessment.

QRA is the most prevalent among these types. In QRA, either an individual or a team can collect the necessary information to conduct the assessment. This method is particularly useful when numerical data are scarce or when resources and records are limited.

QRA is primarily utilized for workplace risk assessments. In this approach, the experience and knowledge of the assessor play a pivotal role. The process involves not only reviewing relevant data but also consulting employees and laborers who are directly involved in the work activities. This consultation is critical for making informed decisions about the potential and severity of risks, followed by categorizing these risks into levels such as high, medium, or low. A key feature of QRA is its assignment of numerical values to different levels of risk, enabling the computation of a risk rating. This rating is typically calculated as the product of the severity and likelihood of a given risk. Consequently, QRA is particularly suited for workplace environments, where it aims to determine the likelihood of someone being at high, medium, or low risk of injury. The assessment involves an evaluation of the severity of potential consequences and the probability of their occurrence, without relying on quantitative tools. QRA is a systematic examination of workplace factors that may cause harm. It facilitates decision-making regarding the adequacy of existing precautions and controls, and whether additional measures are necessary to mitigate identified risks [13].

QRA does not inherently involve numerical data, qualitative expressions are often quantified to estimate the Risk Rating (RR), which represents the product of severity and potential. In QRA, numbers are typically assigned to the severity and likelihood or potential of a consequence, ranging from 1 to 5. The five levels of severity are categorized as insignificant, minor, moderate, major, and catastrophic. Similarly, the likelihood of consequences is classified into five categories: rare, unlikely, possible, likely, and certain [8].

Constructing a risk assessment matrix involves placing the likelihood or potential on the abscissa and the severity on the ordinate. This yields a 5×5 matrix, with each element representing the product of severity and likelihood. The magnitude of these elements reflects the risk rating. The ratings are classified into three categories: low (RR ranging from 1 to 5), medium (RR ranging from 6 to 12), and high (RR ranging from 15 to 25). Risks with a high rating necessitate immediate action, while those with a medium rating may allow for delayed measures, and a low rating might not require further action. Ultimately, QRA is descriptive and heavily relies on the competency and experience of the assessors. Their expertise is crucial in accurately interpreting and applying the qualitative data to the risk assessment process, ensuring that the assessments are reflective of the actual workplace risks.

Semi-quantitative risk assessment employs a methodology that combines qualitative and quantitative elements to articulate the relative scale of risks. This approach utilizes numerical values, primarily in the form of frequency ranges or levels of consequence, to provide a more defined assessment of risk. The use of consequences-likelihood matrices, with consequences plotted on the x-axis and likelihood on the y-axis, enables the classification of risks. This classification leverages expert knowledge, often in scenarios where quantitative data is limited [13]. The foundational aspect of semi-quantitative risk assessment is categorical labeling. This process involves describing the probability, impact, and/or severity of a risk as Very Low, Low, Medium, High, or Very High. Alternatively, a scaling system such as A-F may be used, with each term having a clear and distinct definition [14].

In the semi-quantitative risk assessment approach, various scales are employed to characterize the likelihood of events and their consequences or severities. This method does not necessitate precise mathematical data for analyzing probabilities and their outcomes. Instead, the goal is to establish a hierarchy of risks relative to their quantification, identifying which risks require further review without implying a direct relationship between them.

Conversely, quantitative risk assessment assigns numerical values to risks based on realistic and measurable data. Rather than categorizing risks as high, medium, or low, they are assigned specific numerical values, such as 3, 2, and 1, although the scale can be broader. This type of risk assessment is particularly applicable to industries with significant hazards, such as aviation, chemicals, and nuclear power plants. Quantitative measurements may encompass a variety of factors, including hazards associated with equipment, chemicals, design, and modeling techniques.

Quantitative risk assessment necessitates specialized instruments and procedures for hazard identification, severity consequence estimation, and likelihood determination of hazard actualization. These tools include event trees, sensitivity analysis, simulation software, and others. The use of these tools enables a more detailed and precise assessment of risks, especially in scenarios where high-risk factors are present.

Based on the aforementioned discussion, it can be concluded that each category of risk assessment—qualitative, quantitative, and semi-quantitative—has its own set of advantages and disadvantages. QRA is advantageous in its speed and ease of implementation, as it does not rely on numerical measurements. This simplicity allows for prompt execution. However, it is inherently descriptive and heavily reliant on the competency and experience of the assessors. As a result, there is a degree of subjectivity involved, with the potential for variability in determining probabilities and consequences.

In contrast, QRA is more objective and offers detailed decision-making. However, this method is time-intensive and can be complex, as quantitative data are often challenging to collect or measure. This complexity may limit its applicability in certain situations.

Semi-quantitative risk assessment serves as an intermediary approach, balancing the qualitative and quantitative methods. By evaluating risks on a scale, it mitigates some of the limitations found in purely qualitative or quantitative assessments. This approach offers a more nuanced evaluation, combining the ease of qualitative assessments with the specificity of quantitative methods.

Ideally, a risk assessment should commence with a straightforward qualitative evaluation, incorporating any relevant and applicable good practices. In certain circumstances, it may be necessary to supplement a qualitative assessment with a more precise semi-quantitative or quantitative evaluation [8]. This combined approach allows for a comprehensive assessment that leverages the strengths of each method while addressing their individual limitations.

In risk assessment, the analyst estimates the probability of occurrence of identified hazards, which can be numerous and complex, especially in scenarios involving novel processes and operational parameters. For instance, in large chemical process plants or nuclear installations, detailed and sophisticated risk assessments are necessary. In such cases, it is appropriate to conduct a detailed quantitative risk assessment in addition to a simpler qualitative assessment [7]. Quantitative risk assessment involves obtaining a numerical estimate of risk based on a quantitative analysis of event probabilities and consequences. This process requires the use of specialized quantitative tools and techniques for hazard identification and to estimate the severity of potential consequences as well as the likelihood of hazard realization [7]. Given the complexity of these techniques, which are sometimes supported by software, the assessments need to be carried out by suitably qualified and experienced assessors. These techniques are particularly relevant for assessing risks related to business objectives and analyzing the adverse financial effects of incidents on the company. The outcomes of quantitative risk assessments are numerical estimates of risk, which can then be compared to numerical risk criteria during the risk evaluation stage. This quantitative approach provides a measurable and objective basis for comparing and evaluating risks, thereby facilitating informed decision-making in the management of these risks.

In quantitative risk assessment, the focus is on estimating the probability of occurrence of an undesirable top event. This estimation is achieved by accurately sequencing the sub-events that lead to the top event, which is responsible for releasing the hazard. Each of these sub-events is assigned a probability of occurrence. These probabilities are then logically combined to derive the overall probability of the top event occurring [8].

This quantitative risk assessment procedure is greatly aided by the use of logic diagrams, which provide graphical representations of the sequence of events. The most commonly utilized diagrams in this context are the Event Tree Analysis (ETA) and Fault Tree Analysis (FTA) techniques [15]. Fault Tree Analysis is a method that seeks to identify the root causes of a specified final event. It employs deductive reasoning, working backward from the final event to trace its origins. Event Tree Analysis, in contrast, uses inductive reasoning. It starts with an initiating or primary event and works forward to define the subsequent events and paths that result from this initial occurrence [8]. Both these techniques are invaluable in pinpointing specific events or parameters that should be monitored or measured periodically. This regular monitoring is crucial for the effective implementation of the quantitative risk assessment method, as it provides ongoing data and insights necessary for accurate risk estimation and management.

Despite its significance, risk assessment in water bottling factories often faces a dearth of resources. However, the increasing concern over water scarcity and the quality of drinking water is driving more investments towards water treatment and bottling processes. Water-related risks, which can potentially impact production, health, safety, and income, necessitate a tailored assessment to identify and effectively address specific risks associated with drinking water production [16].

In an effort to enhance the bottling process for spring waters, a study team conducted a comprehensive analysis of Monopolis SA's adherence to environmental and occupational health and safety standards. The team synthesized a risk assessment focusing on occupational diseases and injuries across all the company's workplaces. This synthesis included an array of control measures designed to either eliminate or significantly reduce risks to an acceptable level for all workplaces within the organization [17].

2. METHODOLOGY

The following sections discuss the methodology adopted for this case study. Investigation of both quantitative and qualitative aspects of occupational and health risks is essential to this work because the workplace must be safe, and employees must also believe it is secure.

2.1 The case study background

Nestlé Pure Life Jordan Factory in Maan City was chosen as a case study to conduct a risk assessment. Jordan, which has been ranked as the second water-scarce country in the world. It is primarily arid. About half of its 11 million residents are not Jordanians. Ma'an City is the home of Jordan's Nestle Pure Life water bottling factory.

Ma'an City is located in the southern Jordanian desert, 218 kilometers from Amman, the country's capital. Ma'an City has about 50,350 residents, according to Worldometer.

The city is an important transportation hub on the current Desert Highway and the historical King's Highway. Most of its population work in trade. Ma'an experiences long, hot summers that are dry and clear, as well as chilly winters that are typically clear. It is 1,000 meters above sea level. It serves as Ma'an Governorate's administrative hub.

The objective of this study was to conduct a comprehensive risk assessment of Nestlé's (Pure Life's) Jordan factory in Maan city. Nestlé Pure Life brand started in 1860 when pharmacist Henry Nestle developed specialized food for infants whose mothers could not breastfeed. Soon, the recipe he formulated was sold throughout Europe [18]. Nowadays, it is one of the world's largest food and beverage companies. It has over 2000 brands ranging from global icons to local favorites and is present in 187 countries worldwide [18]. In 1998, Nestle launched the Pure Life water brand to help meet the global need for safe drinking water with a pleasant taste at an affordable price. Currently, Pure Life bottled water is available in more than 20 countries.

Nestle's Jordan factory was established in 1995 under the name "Nestle Jordan Trading Company" in Ma'an, Al-Husayniyah [18]. This factory specializes in water bottling (Pure Life). The factory has 111 employees, with an area of 4683 m^2.

The current study investigates the occupational health and safety status at the Nestlé Pure Life Jordan Factory by applying the semi-quantitative risk assessment. The facility comprises three distinct areas; production, storage, and bottling. The assessment followed the standard technique that starts with identifying hazards and their causes, determining how and who is affected, hazard evaluation, and determining control measures. Identifying hazards involved their detailed description. Further, risk evaluation and analysis aimed to assign the identified hazards a risk rating based on their likelihood and severity. Finally, a risk matrix constructed to summarize the factory's safety status followed by the proposed risk controls.

2.2 Risk assessment

In the current research, the ability to estimate the likelihood and the severity of the impact of a hazard was a significant drawback of the risk assessment process. The interviews with workers and safety officers, incident records, and observations formed the basis of this estimation. The associated uncertainties of risk may lead to underestimates. Therefore, the factory's safety department must continually validate and update these estimates by comparing them to event logs and considering new controls and modifications to processes. Data verification, uncertainty analysis, and simulations may also improve estimates. Furthermore, employee training can have a profound effect on risk estimation. Identifying potential hazards and assessing associated risks requires adequate expertise and knowledge.

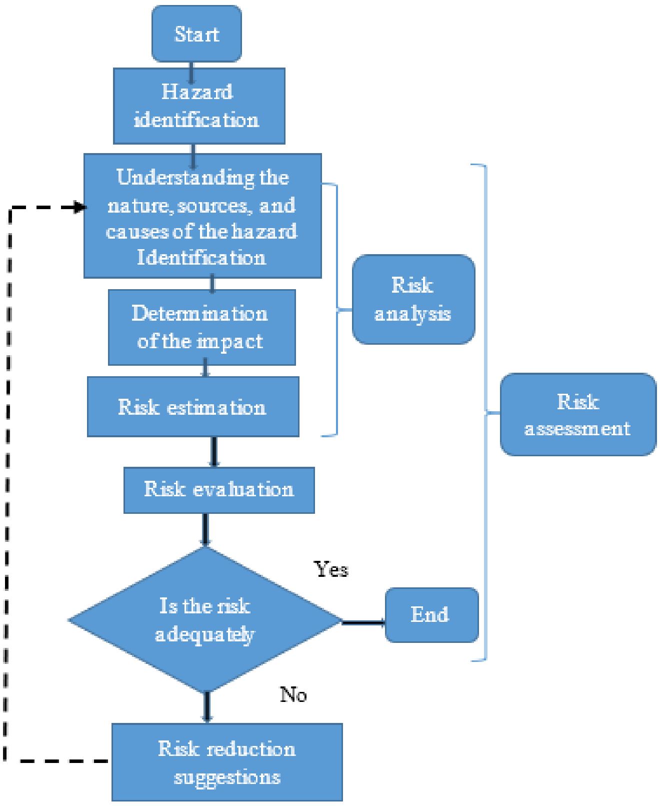

Figure 1. Risk management flowchart (adapted from ISO-IEC 31010) [12]

A standard risk assessment began with hazard identification using various techniques to identify the existing hazards and their potential causes, then assessing them according to their expected effects, and ending with developing a list of control measures and precautions to eliminate or mitigate each hazard's effects and reduce its risk. Usually flow charts are used to standardize risk assessment, a flowchart adapted from ISO-IEC 31010 [12] shown in Figure 1 illustrates the risk management process used in the current study.

The flow chart outlines the necessary steps that are required to carry out the risk assessment properly. The five steps of risk assessment are presented in this chart and can be performed in three stages. The first stage includes hazard identification step, in this stage several methods and ways can be conducted to highlight and recognize the existed hazards. The second stage is risk analyzing, in this stage the assessor should understand the nature, sources and causes of the identified hazard then determine the impacts and estimates the potentials of the risk needed for evaluation step. The last stage includes risk evaluation followed by proposing control plans, administrative actions, incident resolution and risk mitigation techniques required to recover the identified hazards then revising these controls to ensure that safe environment is achieved. Figure 2 represents a diagram explains the sequence of how to perform each of these steps.

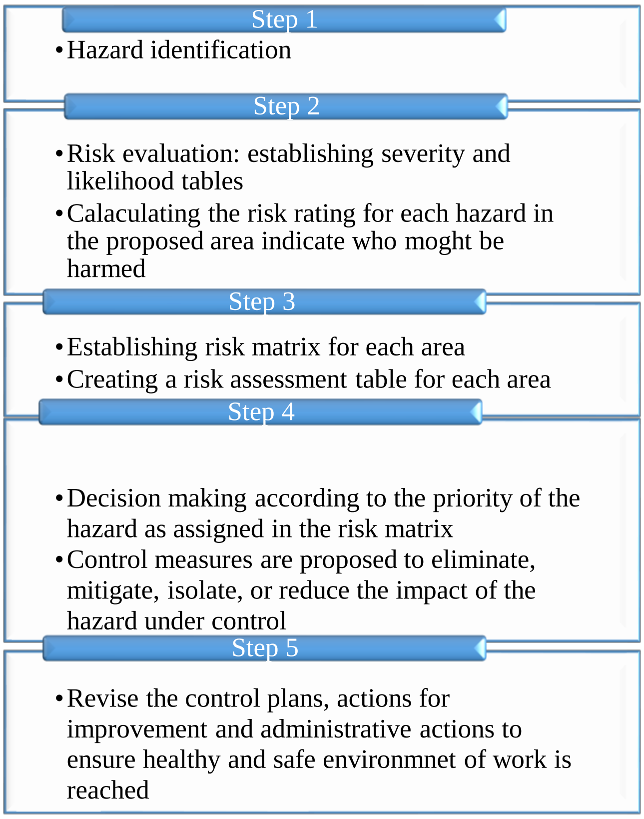

Figure 2. Steps of risk assessment

2.2.1 Hazard identification

Hazard Identification is a proactive process that aims to identify hazards and eliminate or minimize/reduce the risk of injury/illness to workers and damage to property, equipment, and the environment. It also allows commitment and due diligence to a healthy and safe workplace [9]. Because of that, it is the first step of any risk assessment process which includes observation, investigation, inspection, record examination and process analysis. The assessor should carefully look around the workplace and vigilantly observe what may cause harm. One should verify how people work, operate the plant, use equipment, what and handling chemicals and materials, and work S.O.Ps and practices.

The factory's production, storage, and bottling areas all underwent hazard identification. This technique is analogous to safety or a loss prevention review [19, 20]. Table 1 describes the methods used for hazard identification. The research team, therefore, conducted walkthroughs, checks, and visits to factory premises to look for any actions, circumstances, or sources that could pose a risk. The inspections accompanied by safety officers, discussions with department heads, and verifying and listening to employee concerns revealed several hazards. The implemented measures were documented and considered when classifying risks and proposing further controls.

Table 1. Methods for hazard identification

	Method Description
1	Walkthroughs and visits of all factory premises
2	Inspections accompanied by safety officers
3	Examination and verification of worker's concerns
4	Discussions with heads of factory departments
5	Gathering information about the number of workers in the factory and the nature of the works
6	Use brainstorming to decide whether the workers are more likely to be exposed to a hazard

2.2.2 Risk evaluation

The development of risk tables for the recognized hazards in the three areas was made possible by the use of a qualtitative risk assessment. Once the risks have been prioritized and arranged according to how hazardous they were, recommendations for what should be controlled, corrected, modified, or improved could be made.

Risk evaluation is not a random process. It must comply with specified risk criteria to classify the consequences and probabilities of the hazards in a qualtitative method, as per ISO 31000 and ISO 45001 [21, 22]. The risk criteria are terms of reference used to evaluate the significance of an organization's risks and determine their risk ratings [17, 19, 23].

Tables 2 and 3 summarize the risk criteria used as a guide to help rank the risk of hazards. Depending on the severity, the consequences are classified into five categories, from "insignificant" to "catastrophic" for the greatest severity. There are also five levels of likelihood, from "rare" to "almost certain" for the highest probability.

Table 2. Severity-consequence levels

Level	Level Name	Level Description
1	Insignificant	Minor injury- First aid treatment, low financial loss
2	Minor	Minor injury- Medical treatment, medium financial loss
3	Moderate	Over 7-day injury, high financial loss
4	Major	Significant injuries, loss of production, major financial loss
5	Catastrophic	Death, permanent disabilities, substantial financial loss

Table 3. Probability (likelihood) levels

Level	Level Name	Level Description
1	Rare	may occur only in exceptional circumstances
2	Unlikely	could occur at some time
3	Possible	might occur at some time
4	Likely	will probably occur in most circumstances
5	Almost certain	expected to occur in most circumstances

Based on interviews with workers and safety officers as well as records' examination and observations, a table of likelihood and severity was developed. The likelihood and severity of hazards were evaluated on a scale of 1 to 5. A risk rating (RR), which ranged from 1 to 25, was computed by multiplying the hazard's severity by its likelihood. The hazards were then ranked according to their risk rating using a 5×5 risk matrix and grouped using a traffic light analogy (see Table 4). The medium-risk (RR 6-12) hazards in the orange zone require action soon, while those in the red zone (RR 15-25) demand immediate action. The green area, however, contains low-risk hazards (RR 1 to 5), which might allow for delayed control actions [6].

Table 4. Proposed risk matrix

		Rare	Unlikely	Possible	Likely	Certain
S	**1**	**2**	**2**	**3**	**4**	**5**
Insignificant	1	1	1	3	4	5
Minor	2	2	2	6	8	10
Moderate	3	3	3	9	12	15
Major	4	4	4	12	16	20
Catastrophic	5	5	5	15	20	25

3. RESULTS

This section presents, analyzes, and discusses the study's findings about its goal of enhancing workplace health and safety at the Nestle Pure Life water bottling plant. The risks found in the factory areas are discussed in the first section, followed by a risk assessment utilizing the risk matrix technique and the derived risk ratings (i.e., risk quantification). Risk rating (RR) is the multiplication of likelihood with the severity. Assigning values to likelihood and severity has considered the present safety controls. Each area is then assigned a list of new safety measures. These safety controls included both administrative and engineering ones.

3.1 Identified hazards

The hazard identification process took into account events, incidents, and conditions that may introduce hazards into the workplace. Therefore, this section aims to compile a thorough list of all hazards, their assessment, severity, control measures, and all factors or conditions that may cause harm. Upon the completion of hazard identification, the implemented controls were documented and considered when classifying the risk.

3.1.1 Hazards identified in the production area

In addition to the piping system, storage tanks, and cleaning-in-place (CIP) tanks, the factory's production area comprises several units, including (CIP), reverse osmosis (R.O.), filtration, and U.V. Table 5 describes the identified hazards in the production area.

3.1.2 Hazards identified in the storage area

The factory has three main stores: final products, chemicals, and general stores (e.g., labels, packaging rolls, and cartoons). Hazards identified in these areas are listed and described in Table 6.

3.1.3 Hazards identified in the bottling area

This area consists of four main lines; bottles blowing line, filling line, labeling line, and palletizing line. Hazards identified in these lines are listed and described in Table 7 below.

Table 5. Hazards identified in the production area

Hazard	Hazard Description
Water spillage	Water is pumped from a well through a piping system to different stages of the production process. This high flow rate may experience leaks and form slippery areas in many locations.
U.V. radiation	Many U.V. points are distributed along the production line; these points are used in the disinfection of the micro-organisms. Over exposure to UV can harm humans in many ways, such as eye and skin damage. It also may cause damage to materials.
Chemicals usage	Some chemicals are used in the production process, such as: Chemical in R.O. unit: R.O. membrane cleaning chemicals, detergents, scale inhibitors and corrosion inhibitors, biocides, antifoulants, de-chlorinators, and flocculants. Chemicals in the CIP unit: Nitric acid, phosphoric acid, sodium hydroxide, chlorine, and hydrogen peroxide.
Hot water	The last stage of the CIP is to rinse the inside of the pipe with hot water from the CIP process. Cleaning storage tanks.
Pressure build-up in the piping system	That could happen due to a closed valve, blocked filter, or any clog in the pipes. That could result in a pipe rupture and releasing of high-pressure water, which poses many hazards to the workers and property, such as exposure to a high-pressure water jet, creating electrically-conducting areas, and slipping. This hazard has been experienced many times in the factory.
Pressurized air	A high pressure exists in the pneumatic valve system, which operates at 7 to 40 bar.
Work in confined spaces	The interior of storage tanks is cleaned regularly to prevent the development of bacteria; this cleaning is performed by the worker using hot water and chlorine at low concentrations.

Table 6. Hazards identified in the storage area

Hazard	Hazard Description
Tripping	As a result of many obstructions in the storage area.
Noise	High noise levels resulting from trucks' engines, conveyor belts, and other equipment could lead to hearing problems for workers within the storage area.
Fragile roofs	The ceiling of the storage area is fragile (metallic) and about to collapse, primarily upon exposure to a strong wind.
Improper chemical" storage areas	The team noticed some hazardous chemicals being stored in an old, deserted workshop containing sharp instruments and unused equipment that fills the place.
Fire	Fire hazard is one of the major concerns. Further analysis of this hazard, considering the existing fire protection systems, is needed.

3.2 Risk assessment

In the current research, the ability to estimate the likelihood and the severity of the impact of a hazard was a significant drawback of the risk assessment process. The interviews with workers and safety officers, incident records, and observations formed the basis of this estimation. The associated uncertainties of risk may lead to underestimates. Therefore, the factory's safety department must continually validate and update these estimates by comparing them to event logs and considering new controls and modifications to processes. Data verification, uncertainty analysis, and simulations may also improve estimates. Furthermore, employee training can have a profound effect on risk estimation. Identifying potential hazards and assessing associated risks requires adequate expertise and knowledge.

Because of the lack of data, qualntitative risk matrix of likelihood and severity was used to determine the proper controls to eliminate or mitigate each safety hazard to an acceptable level. Based on the risk matrices developed for the three areas, risk evaluation tables were then created for each. It allowed for classifying hazards as high, medium, or low risk.

3.2.1 Risk matrix for the production area

A risk matrix for the production area was created based on the hazards identified in that area, as illustrated in Table 8. The hazards were then arranged in descending order according to their risk rating (R.R.), as exhibited in Table 9.

Table 7. Hazards identified in the bottling area

Hazard	Hazard Description
Robotic palletizer	A robotic palletizer is a machine configuring pallets and warping the pallets by multiple layers of packaging roll. For safety, the palletizer is isolated by a cage, but when the worker needs to reload a packaging roll, he must enter and reload a new one. It looks safe, but the problem is that it depends on the worker's behaviour, as if the machine is operated while the worker is still inside the cage, the worker could receive a stroke by the palletizer arm.
Heavy weights lifting	The manual reloading of the packaging roll in the robotic palletizer requires lifting a roll weighing (50 Kg) and then installing the packaging roll on the rolling cylinder.
Poor house keeping	Obstructions are observed in this area, such as waste from the bottle formation process, deformed bottles, cartoon boxes, and more. These could introduce a hazard.
Unreachable fire-fighting systems	During the walk-through, team noticed that many fire extinguishers and hose reels were surrounded by different obstacles that made them difficult to be reached in emergencies.
Noise	Continuous exposure to high levels of sound results from machines, belts and equipment in the workplace during the operation.

Table 8. Risk matrix for production area

Likelihood	Rare		Unlikely	Possible	Likely	Certain
Severity	**1**	**1**	**2**	**3**	**4**	**5**
Insignificant	1					
Minor	2					
Moderate	3			Hot water		
Major	4		Water Spillage		chemicals	
Catastrophic	5		U.V. radiation Pressurized air Work in confined spaces	Pressure build-up in the piping system		

Table 9. Hazards ranking for production area

	Risk	Hazard
1	High (15-25)	Chemicals use (R.R. 16) Pressure build-up in the piping system (R.R. 15)
2	Medium (6-12)	U.V. (R.R. 10) Pressurized air (R.R. 10) Hot water (R.R. 9) Water spillage (R.R. 8)
3	Low (1-5)	-

Table 10. Risk matrix for storage area

	Rare		Unlikely	Possible	Likely	Certain
S	**1**	**1**	**2**	**3**	**4**	**5**
Insignificant	1					Tripping
Minor	2					
Moderate	3			Improper chemicals storage		
Major	4					Noise
Catastrophic	5			Fragile roofs Fire		

Table 11. Hazards ranking for storage area

	Risk	Hazard
1	High (15-25)	Noise (R.R. 20) Pressure Fragile roofs (R.R. 15) Fire (R.R. 15)
2	Medium (6-12)	Improper chemicals storage (R.R. 9)
3	Low (1-5)	Tripping (R.R. 5)

Table 12. Risk matrix for bottling area

		Rare	Unlikely	Possible	Likely	Certain
S	**1**	**1**	**2**	**3**	**4**	**5**
Insignificant	1					
Minor	2					
Moderate	3				Poor house keeping	Noise
Major	4				Heavy weights lifting	
Catastrophic	5	Robotic palletizer	Unreachable fire-fighting systems			

Table 13. Hazards ranking for bottling area

	Risk	Hazard
1	High (15-25)	heavy weights lifting (R.R. 16)
		Noise (R.R. 15)
		Poor housekeeping (R.R. 12)
2	Medium (6-12)	Unreachable fire-fighting system (R.R. 10)
3	Low (1-5)	Robotic palletizer (R.R. 5)

3.2.3 Risk matrix for the bottling area

The bottling area contains several hazards and shown in the risk matrix presented in Table 12. The hazards were then arranged in a descending order as per their R.R.s as exhibited in Table 13.

The reviewed literature revealed the use of risk assessment methods in the absence of data; this circumstance also occurred in thses studies [24-30]. Factors that influenced the approach used in the current risk assessment included time, funds, human resources, and corporate perceptions of occupational health and safety. Altenbach [30] made similar observations. In addition, the number and competency of the employees involved in the evaluation were crucial factors [8]. These factors may significantly affect the identification of hazards and the associated risk rating (R.R.). As a result, other methods for identifying hazards and evaluating risks may be necessary. Hazard indices, HAZOP studies, fault tree analysis, etc., are additional techniques for identifying hazards.

Most qualtitative assessments relate to water and food industries [28, 29]. These assessments often use a 5×5 matrix technique, with the likelihood at the y-axis and the consequences on the x-axis [31, 32]. The risk assessment matrix permits management and executives to make operational decisions that mitigate or eliminate hazards.

Moreover, the quantitative approach may serve as a reliable tool to reveal the potential occupational health and safety risks, but only from an overall perspective [33-36]. However, the demand for greater precision in risk assessment and hazard identification necessitates the application of other approaches as mentioned earlier. Besides, the qualtitative approach is easier to use than the quantitative one and allows one to compare and evaluate multiple scenarios at the same time [28]. Furthermore, it is easily interpreted.

3.3 Hazard risk ratings

Table 14 compares the percentages of the risk rating groups for the three areas. As can be seen, most hazards are medium-risk, followed by high- and low-risk hazards in the production and bottling areas. The storage area is the most hazardous as the high-risk hazards make about 60% of the identified ones.

As shown in Table 15, the high-risk hazards were about 41% of the identified hazards in the entire factory, implying the existence of an unsafe situation that could lead to catastrophic consequences of property damage, injuries, or even fatalities. Therefore, the corporation’s top management must take immediate action to reduce or eliminate such risks. Likewise, the medium-risk hazards, which need solving soon, were about 47% of the total hazards. However, low-risk hazards were only about 12% of the identified hazards. In storage and bottling areas, the noise risk rating (R.R.) was high, with the storage area being the most hazardous. The noise level was above the eight hours-permissible exposure limits. Overall, occupational health and safety need great and urgent attention. Similarly, earlier studies assert that water industry workers are at risk of hot water, noise, chemical spills and exposure, slippery walkways, working in confined spaces, and other factors [37-39].

Table 14. Percentages of the risk rating (R.R.) groups for the three areas

	High-Risk Hazards	Medium Risk Hazards	Low-Risk Hazards
Production	29%	71%	0%
Storage	60%	20%	20%
Bottling	40%	40%	20%

Table 15. The risk rating (R.R.) groups for the three areas

Area	High-Risk Hazards	Medium Risk Hazards	Low-Risk Hazards
Production	2	5	0
Storage	3	1	1
Bottling	2	2	1
Total	7	8	2

3.4 Risk control revise steps

Risk assessment tables have been created for the factory sections, as shown in Tables 16, 17, and 18. A risk assessment was conducted for each of the hazards identified in the preliminary stages of the investigation. The tables include the following details for each hazard: who might be harmed, existing controls, a description of the impact, severity (S), probability (P), risk score, and risk rating (R.R.). In addition to identifying control measures based on risk ranking, the hierarchy of controls was also considered [21].

The elimination of hazards from the workplace is the first step in the control hierarchy. Then comes substitution, mitigation (engineering and administrative controls), and personal protective equipment. The administrative control, for instance, training programs, policies, and regulations, provide the framework for a department's risk control program, thereby ensuring workplace safety.

According to the hierarchy of control, personal protective equipment (PPE), which includes clothing and equipment worn by employees for protection against health and safety hazards, is the lowest control measure [40].

The risk assessment tables for the studied areas include a summary of the recommended controls for the identified hazards. The proposed controls shown in Tables 15, 16, and 17 range from hazard elimination, isolation, and mitigation to using personal protective equipment (PPE), while some hazards (2 hazards) require further investigation. Exposure to hot water in the production area, fragile roofs in the storage area, and heavy weight lifting in the bottling area could all be eliminated. Regular reviewing of control plans and reevaluating existing controls are recommended for improved safety.

In addition to implementing the new risk controls, the factory's safety management department should continuously analyze, monitor, and review risks since hazards change as work circumstances and requirements change. Such conditions may include adopting new technologies and S.O.Ps, hiring new employees, etc. The safety management department must continuously assess risks and evaluate control measures to ensure that evolving hazards are mitigated or eliminated.

Table 16. Risk assessment for the production area

Hazard	Who Might be Harmed	Current Controls	Impact	S	P	Risk Score	Risk Rating	Needed Controls
Water spillage	Production line operators	None	Slipping, exposure to water containing acids or bases which could cause bone fracture, skin irritation.	4	2	8	Medium risk	Enlarge the drainage manhole to avoid flooding in case of spillage, regular leak checks of tanks, pipes, valves, joints, chemical supply connections, corroded areas. Ensure workers wear proper PPE including safety shoes with non-skid soles, googles, chemical resistant gloves, chemical resistant coats. Warning signs of potential hazards what type of precautions must be taken. Safety precautions in S.O.Ps
U.V. radiation	Production line operators	U.V. units casing	Long-term exposure could cause cancer, hair-loss and genital disorder	5	2	10	Medium Risk	Trained workers should only operate UV units. Restrict access of others to avoid accidental exposure. Using work shifts system. Operators should keep a safe distance from any U.V. point Use of appropriate PPE, which include gloves, lab coat with no gap between the cuff and the glove, and a UV resistant face shield. Work procedural safety measures. Use of plastic shielding and fail-safe interlocks. The distance from which workers operate the equipment must be assessed as well as the duration of exposure. The area is evacuated before starting operation. No person in line of sight of the device during operation. There should be warning labels on all UVC disinfection devices accordance with the IEC 61549-310-1. A. UV-resistant eyewear (goggles/face shields/safety glasses). Protective wear/clothing, which covers exposed skin. Make sure the UV device is shut off when the protective enclosure is open. Ventilation may be required to exhaust ozone and other airborne contaminants produced by UVC radiation from nearby of UV device.
Chemicals	R.O. unit Production line operators	PIPE	Severe irritations, burns, …etc.	4	4	16	High Risk	Trained workers should only operate RO units. Follow the manufacturer's safety instructions and handling procedures. Regularly inspect and maintain the RO system to prevent leaks. Chemicals should be dealt with as in MSDSs. Train operators on proper emergency response

								procedures in the event of a leak. Follow the manufacturer's safety instructions and handling procedures of RO units. Use proper PPE.
Hot water	Disinfection (CIP) operators	PIPE	severe burns	3	3	9	Medium Risk	Trained workers should only operate (CIP). Use automated water nozzles to clean the interior of tanks to eliminate human exposure. Propper PPE including face shields, aprons, etc.
Pressure build-up in piping system	Production line operators	None	High-pressure water jet could push the operator on a solid surface or energized equipment, in worst case; death and extensive injuries could be expected	5	3	15	High Risk	Regularly inspect and maintain all high-pressure equipment to ensure safe operation. Train operators on the proper use and maintenance of high-pressure equipment. Install pressure relief valves to prevent over-pressure incidents. Use proper protective equipment, such as steel-toed shoes, when working near high-pressure equipment. Further analysis is needed using one of the QRA techniques.
Pressurized air	Production line maintenance operators	None	Could cause a severe eye injury, hand penetration or cut during maintenance	5	2	10	Medium Risk	Regularly inspect and maintain all high-pressure equipment to ensure safe operation. Wear proper PPE during operations near pneumatic valves, shut off air valve, and vent all accumulators and lines during maintenance. Use proper protective equipment, such as steel-toed shoes, when working near high-pressure equipment. Further analysis is needed using one of the QRA techniques.
Work in confined spaces	Disinfection operators	PIPE	Asphyxiation, excessive heat, irritations, lack of communication…etc.	5	2	10	Medium Risk	Prevent working in a confined space without permit-to-work procedure; keep communications, properly trained people. Keep space well-ventilated. Use of respiratory protective equipment beside other PPE.

Table 17. Risk assessment for storage area

Hazard	**Who Might be Harmed**	**Current Controls**	**Impact**	**S**	**P**	**Risk Score**	**Risk Rating**	**Needed Controls**
Tripping	Storage area operators	None	Could cause moderate injuries	1	5	5	Low Risk	Remove the obstructions from the pathways, increase lighting. Clear signs to alert to changes in level, Regular and proper maintenance of floor paving. Proper drain covers. Avoidance of the use of extension cables. No loose clothing is permitted. Use non-skid shoes.
Noise	Storage area operators	None	Tinnitus and noise-induced hearing loss on long-term exposure	4	5	20	High Risk	Lubricate the equipment regularly, wear earplugs or alternative PPE. Warning signs of high-level noise (above 85 dB). Appropriate work schedules with adequate rest times. Restrict access of other employees to high noise level. Regular hearing medical check.
Fragile roofs	Storage area operators	None	Falling roof parts could cause in severe injuries and even death	5	3	15	High Risk	Replace defected roofs. Wear resistant helmets and safety shoes against falling objects.
Improper chemicals storage areas	Storage area operators	None	Exposure to chemicals and sharp edges could result in burns, irritations, injuries…etc.	3	3	9	Medium Risk	Isolate chemicals, handle and store as per the related MSDSs, regular housekeeping. Proper PPE.
Fire	Storage area	Sprinkler system and	Could result in asphyxiation, severe	5	3	15	High Risk	Ensure designated smoking area is distant from flammable materials. Flammable chemicals are

	operators	smoke extraction system	burns, and death					totally isolated. Proper housekeeping, such as preventing materials and dust from accumulation. Regular servicing of electrical equipment and network to prevent sparks. Proper electrical earthing to prevent static sparks. Further analysis of this hazard is recommended.

Table 18. Risk assessment for bottling area

Hazard	Who Might be Harmed	Current Controls	Impact	S	P	Risk Score	Risk Rating	Needed Controls
Robotic palletizer	Palletizer and maintenance operators	System's safety functions (integrated locks)	Robotic motion and Palletizers arm stoke could cause in skull crush and death. Crushing due to accidental release or expulsion of a box.	5	1	5	Low Risk	Provide operators, maintenance and other key stakeholders with comprehensive training on equipment hazards, safety features, safe operation, entry into the robot cell. Regular training, use shift working system. Use PPE. Regular check that system safety features are functioning. Monitor robot speed to avoid associated risks of robot kinetic energy and of the pallet objects. Area scanning system that will monitor the presence of humans and slow or stop the robot cell if someone is too close. Signs to warn employees from approaching robot area. Fences to prevent the operator from entering a dangerous area. A mechanism to stop the palletizing robot when the safeguard is opened.
Heavyweights lifting	Palletizer reloading operators	None	Back injuries and may lead to permanent disabilities	4	4	16	High Risk	Use of electrical roll lifting equipment
Poor housekeeping	Bottling area operators	None	Could result in several accidents which lead to severe injuries	3	4	12	Medium Risk	Remove obstructions, set a specific places to dispose the defected bottles
Unreachable fire-fighting systems	Bottling area operators	None	Could lead to asphyxiation, severe burns, and death	5	2	10	Medium Risk	Remove obstructions, ensure easy access to any firefighting equipment
Noise	Bottling area operators	None	Hearing impairment, hearing loss on long-term exposure	3	5	15	High Risk	Regular lubrication of machines, use ear muffs, ear plugs…etc.

4. CONCLUSIONS

The following conclusions are made based on the case study's findings. A suggestion for future research also follows these conclusions:

- By implementing a qualtitative risk assessment, workplace hazards may be eliminated or mitigated. The qualtitative risk assessment is a methodical approach to examining and rating pre-identified hazards, many of which were determined using a purely qualitative approach that may have resulted in an incomplete inventory of them. Based on that, it may serve as a reliable tool to reveal the potential occupational health and safety risks, but only from a general perspective. Some hazards remain almost concealed, making it difficult for the safety officer to identify them.
- Nestlé Pure Life Jordan does not need new infrastructure; instead, several modifications are required, including the replacement of defective roofs, the use of electrical roll and lifting, the segregation of chemical storage, and personnel training. It is also necessary to make quite a few ergonomic and procedural changes.
- The risk assessment of the identified hazards revealed the existence of an unsafe workplace that requires the corporation’s top management to take immediate action to reduce or eliminate the hazards.
- Nestlé Pure Life Jordan employees face many physical, chemical, and ergonomic risks. The related risks range from high (41%), moderate (47%), and low (12%). Further, there is an association between the working environment and exposure to risks and hazards. Minimizing risk exposure may, therefore, enhance the working environment.
- In addition to reviewing safety indicator records,

other approaches, such as fault tree analysis and HAZOP analyses, should be utilized to ensure that the safety officer identifies every hazard.

As a future work, it is recommended to study and investigate the potential psychological and social hazards, and the impact they may have on workers of Nestlé Pure Life Jordan factory.

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