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Analysis Of Occupational Safety Risks in IPAL Units Using the HIRARC Method

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Abstract
Aims. This study analyzes occupational hazards and safety risks in the Wastewater Treatment Plant (WWTP) unit of a major food company in West Java (name and details anonymized for confidentiality).
Methods. The Hazard Identification, Risk Assessment, and Risk Control (HIRARC) method and the fishbone diagram (Ishikawa) were applied.
Result. The results indicate that activities in the WWTP unit present varying levels of risk, with dominant hazards including chemical exposure, slippery work environments, and poorly maintained machinery. The fishbone diagram reveals that workplace accidents are multifactorial, involving human, machine, method, and environmental aspects, while also highlighting the importance of chemical storage control, which, although less frequent, poses significant impacts on worker safety and operational continuity.
Conclusion. These findings align with international standards such as ISO 45001:2018, the ILO Occupational Safety and Health Convention No. 155, and national regulations PP No. 50 of 2012 on Occupational Safety and Health Management Systems (SMK3), emphasizing that hazard identification, risk assessment, and continuous control must be implemented comprehensively to reduce workplace accidents and ensure industrial sustainability.

Keywords: Occupational Safety and Health (OSH); HIRE; Fishbone Diagram; ISO 45001; ILO; PP No. 50/2012; Wastewater Treatment Plant (WWTP)

INTRODUCTION

The instant noodle industry is one of the largest food sectors in Indonesia, with very high consumption. Data from the World Instant Noodles Association (2024) show that Indonesia ranks second globally, with consumption reaching 14.68 billion

servings per year. The instant noodle production process, which involves mixing, steaming, frying, and packaging, produces liquid waste with complex organic characteristics. Liquid waste in the food industry has high levels of Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), and Total Suspended Solids (TSS), making it potentially polluting if not properly treated (Masri, 2013). This emphasizes the importance of the presence of Wastewater Treatment Plants (WWTPs) in maintaining environmental quality in accordance with the Regulation of the Minister of Environment No. 5 of 2014 concerning Wastewater Quality Standards.

In addition to the technical aspects of processing, activities in the WWTP unit pose occupational safety and health (K3) hazards. Exposure to chemicals, mechanical risks from pumps and blowers, and slippery environmental conditions can lead to work accidents. Recent research shows that the Hazard Identification, Risk Assessment, and Risk Control (HIRARC) method is effective for identifying and controlling risks across various food manufacturing sectors (Mahendra & Iftadi, 2021). However, studies that specifically highlight the application of HIRARC to the WWTP unit of the instant noodle industry are still rarely conducted.

The international standard ISO 45001:2018 requires that hazard identification, risk assessment, and continuous control be carried out comprehensively to reduce occupational accidents (ISO 45000, 2018). This principle is in line with the ILO Occupational Safety and Health Convention No. 155 (ILO, 1981) and the national regulation, Government Regulation No. 50 of 2012 concerning the K3 Management System. Therefore, this study aims to identify hazards in WWTP units, assess the level of risk using the HIRARC method, and prepare control recommendations based on fishbone diagrams. The research contribution is expected to strengthen the literature on K3 risk management in the large-scale food sector while supporting the implementation of a comprehensive occupational safety system in industrial waste treatment facilities.

State of the Art: Previous research has shown that HIRARC is effective in identifying and assessing K3 risks, while the Fishbone Diagram is effective in identifying the root causes of accidents. However, the integrated application of both

methods in an integrated manner in the food industry WWTP unit remains very limited.

Research Gap: No study has integrated HIRARC and Fishbone to analyze K3 risks in food-industry WWTP units and to produce control recommendations based on international and national standards.

Novelty: This study offers a risk analysis model that combines hazard identification, risk assessment, root cause analysis, and the development of control strategies for the WWTP unit in the food industry. This approach results in a more comprehensive evaluation than using HIRARC or Fishbone separately

LITERATURE REVIEW

Occupational Health and Safety

Occupational Safety and Health (K3) is a fundamental aspect in the manufacturing and food industries. The main objectives of K3 are to protect workers from occupational accidents and diseases, maintain productivity, and support operational sustainability (ILO, 1981). National regulations, as set out in Government Regulation No. 50 of 2012, require every company to implement a comprehensive K3 Management System. The international standard ISO 45001:2018 also emphasizes the importance of hazard identification, risk assessment, and ongoing control as part of an occupational safety management system (ISO 45000, 2018).

HIRARC Risk Management and Methods

Risk management is a systematic process of identifying, assessing, and controlling risks to minimize their impact. The Hazard Identification, Risk Assessment, and Risk Control (HIRARC) method is an internationally recognized approach in ISO 45001:2018. HIRARC allows for systematic hazard identification, risk level assessment based on probability and severity, and determination of control according to the risk hierarchy (Mahendra & Iftadi, 2021). Research shows that applying HIRARC is effective for designing risk control strategies in large-scale manufacturing, including the food sector.

Fishbone Diagram

Fishbone diagrams, or cause-and-effect diagrams, are used to systematically identify the root causes of problems. The structure of the diagram resembles a fishbone, with the "head" representing the main problem and the "bone" representing causal categories such as humans, machines, methods, and the environment (Tarumingkeng, 2024). In K3, fishbone diagrams help to outline the multiple factors that cause work accidents so that control can be more on target.

Wastewater Treatment Plant

The food industry produces liquid waste with high organic content, such as starches, oils, and fats. Liquid waste from the food industry contains high levels of COD, BOD, and TSS, so it can pollute the environment if not properly treated. To prevent pollution, a WWTP is needed that meets quality standards in accordance with the Regulation of the Minister of Environment No. 5 of 2014 (KLKH, 2014). However, activities in WWTP units also pose significant K3 risks, including exposure to chemicals (chlorine, coagulants, flocculants), mechanical risks from pumps and blowers, and biological risks from microorganisms. Therefore, the K3 risk assessment in WWTP is important to support the sustainability of food industry operations.

State of the Art

Researcher	Research Focus	Key Findings	Limitations
Mahendra & Iftadi (2021).	HIRARC on manufacturing activities	HIRARC effectively identifies and controls K3 risks	Not specifically studying WWTP units
Nurul Ilmi et al. (2023)	HIRARC and Fishbone in the steel industry	The combination of the two methods is able to find the root cause of the accident	Not yet applied to the food industry
Lord (2024)	HIRARC Implementation	Explain the stages of hazard identification, risk assessment, and control	Does not discuss the hazard characteristics of WWTP
Squirting (2024)	Fishbone Diagram	Fishbone effectively analyzes the causes of problems systematically	Not integrated with quantitative risk assessment
This research	K3 risk analysis in the instant noodle industry WWTP unit	Identify chemical, biological, physical, and ergonomic hazards, as well as analyze the root cause	It is one of the studies that specifically integrates HIRARC

Researcher	Research Focus	Key Findings	Limitations
	using HIRARC and Fishbone	and provide control recommendations in accordance with ISO 45001 and Government Regulation No.50 of 2012	and Fishbone in the WWTP unit of the food industry.

Based on the literature review and research findings, several research gaps are as follows.

Gap 1

Most of HIRARC's research is conducted in production or manufacturing settings, whereas studies on Wastewater Treatment Plant (WWTP) units in the food industry remain very limited.

Gap 2

Previous research has generally stopped at identifying and assessing risk levels, without conducting an in-depth analysis of the root causes of accidents.

Gap 3

There have been few studies that integrate HIRARC with the Fishbone Diagram, so the relationship between risk levels and causal factors (human, machine, method, material, and environment) has not been fully explained.

Gap 4

There are no risk control recommendations that directly refer to the ISO 45001:2018 control hierarchy and the SMK3 national regulations for the operational activities of the food industry WWTP.

Gap 5

Specific hazard characteristics in WWTPs, such as exposure to chemicals, biological gases, slippery surfaces, blower noise, and ergonomic activities, have not been mapped simultaneously within a single risk analysis framework.

RESEARCH METHODS

Types of Research

This study uses a qualitative descriptive approach with a case study method. The research focuses on the Wastewater Treatment Plant (WWTP) unit at a large-scale food company in West Java. This approach was chosen because it is well-suited to describing real-world conditions in the field and systematically analyzing potential hazards and occupational safety risks.

Location and Research Object

The object of the research is the operational activities at the Wastewater Treatment Plant (WWTP) unit of a large food company in West Java. The activities observed include physical, chemical, and biological processing.

Analysis Method

HIRARC (Hazard Identification Risk Assessment and Risk Control)

Risk analysis was carried out using the HIRARC method which consists of three main stages: hazard identification, risk assessment, and risk control. Hazard identification is carried out through direct observation, interviews, and documentation of activities in the WWTP unit. Risk assessment uses a matrix that combines *likelihood* and *severity*. Risk control is determined based on the control hierarchy (elimination, substitution, engineering, administrative, and use of PPE) (Tompo, 2024).

Fishbone Diagram

A fishbone diagram is used to trace the root causes of the risks found through HIRARC. This diagram groups causal factors into the categories of humans, machines, methods, materials, and the environment. Research shows that Fishbone is effective in identifying the causes of work accidents in a multifactorial manner (Nurul Ilmi et al., 2024).

Research Flow

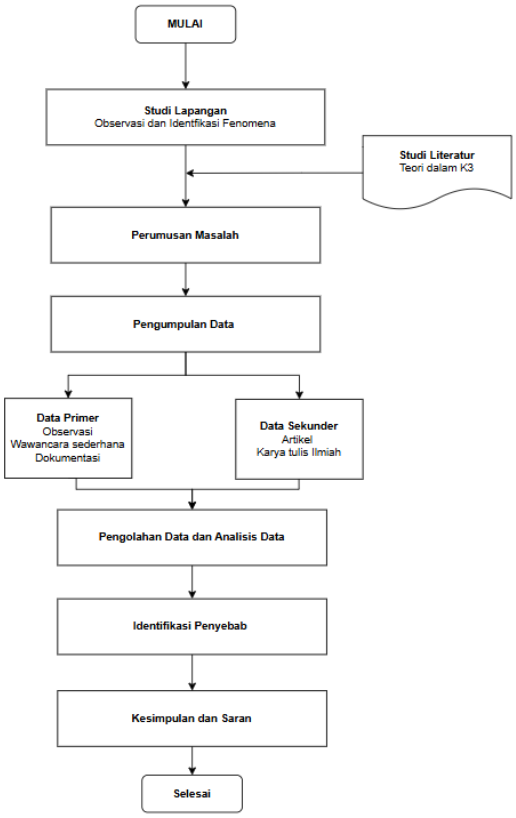


Image 1. Research Flow

Research Instruments

The instruments used include:

1. Observation sheets to record activities and potential hazards.
2. A simple semi-structured interview with WWTP workers and the Head of K3.
3. Documentation in the form of photos, operational records, and internal company data.

RESULTS AND DISCUSSION

Hazard Identification

Yes	Hazard Type	Activities	Danger	Effects of Danger
1	Chemistry	Chemical Dispensing	Exposure to Irritating and Corrosive Chemicals	Worker Injuries and Facility Damage
		Chemical Storage	Potentially flammable and environmentally harmful chemicals	Worker Injuries, Material Losses, and Environmental Impacts
2	Biological	WWTP Unit Monitoring	Inhaled Aerobic Process Waste Gases	Nausea, Dizziness, and Even Respiratory Disorders

Yes	Hazard Type	Activities	Danger	Effects of Danger
3	Physical	Access Area of the WWTP Unit	Slip and Fall Hazards	Minor to Serious Injuries
		WWTP Unit Monitoring	High Noise and Process Overflow	Hearing Loss and Environmental Impact
4	Ergonomics	Chemical Drum Lift	Lifting Techniques and Inappropriate Posture	Back and Muscle Injuries

Risk Assessment

Yes	Hazard Type	Activities	Danger	Effects of Danger	Likelihood	Severity	Total	RiskRating
1	Chemistry	Chemical Dispensing	Exposure to Irritating and Corrosive Chemicals	Worker Injuries and Facility Damage	4 Likely	3 Insignificant	12	High
		Chemical Storage	Potentially flammable and environmentally harmful chemicals	Worker Injuries, Material Losses, and Environmental Impacts	1 Rare	5 Catastrophic	5	Low
2	Biological	WWTP Unit Monitoring	Inhaled Aerobic Process Waste Gases	Nausea, Dizziness, and Even Respiratory Disorders	3 Possible	1 Insignificant	3	Low
3	Physical	Access Area of the WWTP Unit	Slip and Fall Hazards	Minor to Serious Injuries	3 Possible	4 Major	12	High
		WWTP Unit Monitoring	High Noise and Process Overflow	Hearing Loss and Environmental Impact	4 Possible	3 Major	12	High
4	Ergonomics	Chemical Drum Lift	Lifting Techniques and Inappropriate Posture	Back and Muscle Injuries	4 Likely	2 Minor	8	Moderate

Risk Control

Yes	Hazard Type	Activities	Danger	Effects of Danger	Risk Rating	Risk Control
1	Chemistry	Chemical Dispensing	Exposure to Irritating and Corrosive Chemicals	Worker Injuries and Facility Damage	High	Engineering Control: Installation of Safety Shower and Administrative Eyewash : Improvement of SOPs, Chemical Hazard Training, Restriction of PPE Work Areas :Completeness of PPE
		Chemical Storage	Potentially flammable and environmentally harmful chemicals	Worker Injuries, Material Losses, and Environmental Impacts	Low	Engineering Control: Availability of Administrative Fire Extinguishers : Routine Inspection of Container Conditions and Recording and Provision of Hazard Signs and Procedures
2	Biological	WWTP Unit Monitoring	Inhaled Aerobic Process Waste Gases	Nausea, Dizziness, and Even Respiratory Disorders	Low	Administrative: SOP for Periodic Air Quality Monitoring and MonitoringAPD: Completeness of PPE Such as Masks, Respirators and others
3	Physical	Access Area of the WWTP Unit	Slip and Fall Hazards	Minor to Serious Injuries	High	Engineering Control: Anti-Slip Flooring and Good Drainage Administration: Signage and Access Restrictions for PPE Authorized Workers : The Availability of Anti-Slip Shoes
		WWTP Unit Monitoring	High Noise and Process Overflow	Hearing Loss and Environmental Impact	High	Engineering Control: Installation of Administrative Silencers : Rolling Work Schedule, Overflow Handling SOPs, and Emergency Training Updates for PPE Operators: Availability of PPE Such as Earplugs or Earmuff
4	Ergonomics	Chemical Drum Lift	Lifting Techniques and	Back and Muscle Injuries	Moderate	Engineering Control: Improvement of Lifting Techniques, and the Availability of Lifting

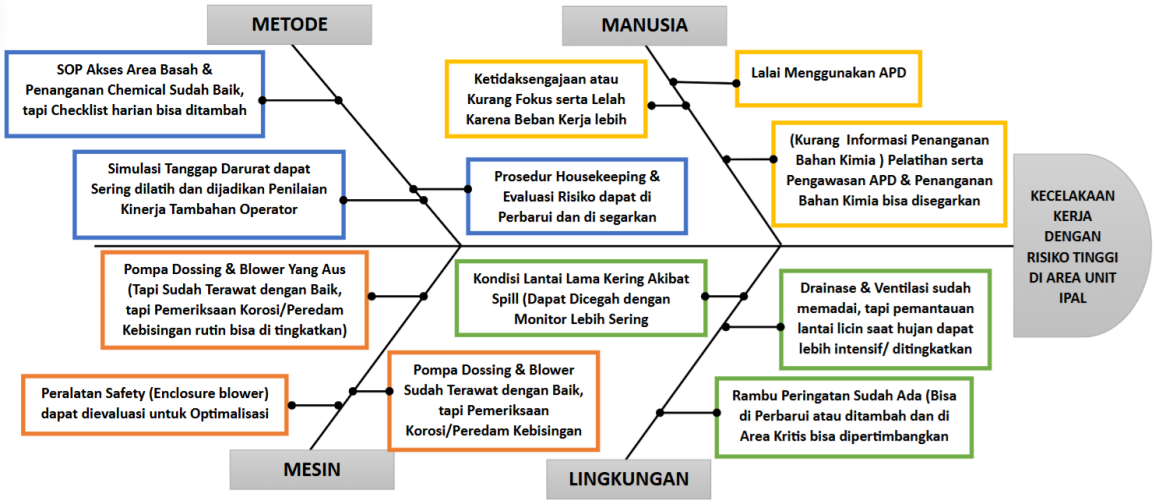
Yes	Hazard Type	Activities	Danger	Effects of Danger	Risk Rating	Risk Control
			Inappropriate Posture			TrolleysAdministrative: Emphasis on SOP for Lifting Techniques

This study found 4 categories of hazards in WWTP units: chemical, biological, physical, and ergonomic. Chemical administration activities (chlorine, flocculant, and coagulant) are at high risk (12) of causing burns, skin irritation, and respiratory distress. Control is achieved through a closed dosing system, SOP adherence, K3 training, and PPE use. Storage of low-risk chemicals (5) still has the potential to cause fires and steam exposure, so SOPs for storage, labeling, segregation, and room ventilation are necessary.

Biological hazards from exposure to aerated gases are categorized as low (3), with control measures including SOP monitoring, air monitoring, and respirator masks. Physical hazards include drowning, slipping, and blower noise, with high risks (12). Control measures include anti-slip flooring, warning signs, anti-slip shoes, blower enclosures, and earplugs/earmuffs. Ergonomic hazards arise from lifting chemical drums, with a moderate risk (8), controlled through training in lifting techniques, trolley use, and ergonomic SOPs. In addition, the overdischarge process at the inlet is moderately risky (9), with control measures including discharge regulation via flow meters and production sanitation SOPs.

DISCUSSION

HIRARC provides a quantitative picture of the level of risk, but does not explain the underlying causal factors. Fishbone is used to multifactor the cause between humans, machines, methods, and the environment, so that control can be directed to the root of the problem, not just the symptoms. Combining the two methods makes the analysis more comprehensive and yields targeted, sustainable control recommendations (Nurul Ilmi et al., 2024).



The Fishbone Diagram is used to trace the root causes of high-risk work accidents in the WWTP unit area. This analysis groups causative factors into four main categories:

Method

Work procedures are already in place, such as SOPs for wet area access and chemical handling, but there are still weaknesses, including inconsistent daily checklists and emergency response simulations that are rarely conducted. This shows that working methods need to be strengthened through periodic evaluations, retraining, and the addition of monitoring mechanisms to more effectively suppress risks.

Humans

Human factors manifest as a lack of focus due to workload, fatigue, and non-compliance with PPE use. In addition, information on chemical handling is still limited, so training and supervision need to be improved. This factor is directly related to the HIRARC results, which indicate a high risk in chemical dosing activities and ergonomics, as work behavior that does not conform to procedures increases the potential for accidents.

Engine

Machines such as dosing pumps and blowers, even when maintained, still have the potential for wear and high noise levels. Corrosion and noise cancellation checks have not been carried out regularly, so the risk remains high. Safety equipment, such as an enclosure blower, also needs to be evaluated for optimal performance. This

engine factor explains why the HIRARC results show noise as a **high risk**, as the technical condition of the equipment directly contributes to hazard exposure.

Environment

The work environment also contributes to slippery floor conditions due to spills, drainage, and ventilation issues, which, although adequate, still require more intensive monitoring, as well as to warning signs that already exist but are not optimally placed in critical areas. This environmental factor is related to the HIRARC results, which indicate a high risk of slipping because the physical condition of the work area increases the likelihood of accidents.

Based on the results of the HIRARC and Fishbone analysis, several improvement steps can be taken to reduce the risk in the WWTP unit:

1) Strengthening SOPs and Training
    - Refresh SOPs for handling chemicals and accessing wet areas.
    - Carry out routine training on the use of PPE and emergency response simulations.
2) Technical Repairs and Routine Inspections
    - Conducting periodic inspections of dosing pumps, blowers, and chemical storage containers.
    - Installing additional noise dampers and repairing non-slip floors in wet areas.
3) Improved Work Environment
    - Add warning signs in critical areas.
    - Strengthen drainage and ventilation systems, as well as monitor the condition of the floor so that it is not slippery.
4) Ergonomics Management
    - Provide lifting aids such as trolleys.
    - Provide proper lifting technique training and manage the workload so that it is not excessive.

The novelty of this study lies in the integration of the HIRARC and Fishbone Diagram methods to comprehensively analyze occupational safety risks in the WWTP unit of the instant noodle industry. Unlike previous research that only assessed the level of

risk, this study linked the results of risk assessment to the analysis of the root causes of accidents to produce more systematic control recommendations based on the risk control hierarchy, ISO 45001:2018, ILO Convention No. 155, and Government Regulation No. 50 of 2012.

1. Integrating HIRARC and Fishbone Diagram in one K3 risk analysis framework.
2. Focus on the food industry WWTP unit, which is still rarely the object of research.
3. Identify four main hazard groups (chemical, biological, physical, and ergonomic) in an integrated manner.
4. Linking the level of risk to the root cause of the accident, so that control recommendations are more targeted.
5. Produce control strategies that are in line with ISO 45001:2018, ILO Convention No.155, and PP No.50 of 2012

CONCLUSION

This study found that the main hazards in the WWTP unit include chemical exposure, blower noise, slippery floors, and ergonomic activities such as drum lifting. HIRARC's analysis shows that some activities pose a high level of risk and therefore require immediate control. The Fishbone Diagram is then used to trace the root cause, which is divided into method factors (SOP is not yet optimal), human factors (fatigue, lack of PPE discipline), machinery factors (worn blowers, leaky containers), and environmental factors (slippery floors, lack of ventilation). The combination of HIRARC and Fishbone provides a comprehensive picture: HIRARC assesses the level of risk, while Fishbone explains the underlying causes. Overall, risk control in WWTP units must be implemented through technical improvements, strengthened SOPs, routine training, and the use of PPE. This approach supports implementing the K3 management system in accordance with ISO 45001:2018 and national regulations.

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