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Mitigating Occupational Hazards in Renewable Energy Manufacturing: A HIRARC Assessment of Enamelling Operations

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Abstract: This study evaluates Occupational Safety and Health (OHS) risks in the enamelling process of a 150-litre solar water heater tank within a renewable energy manufacturing company, using the Hazard Identification, Risk Assessment and Risk Control (HIRARC) method. Conducted through qualitative observations, interviews, and document analysis, the research identified 15 potential hazards—13 high-risk, 1 extreme, and 1 low. Major risks stem from improper use of personal protective equipment (PPE), chemical exposure, and mechanical hazards. Recommended controls include proper PPE usage, engineering improvements, safety training, and better procedures. The findings confirm that HIRARC is effective for systematically identifying and managing workplace risks, fostering a proactive safety culture. The study emphasizes the need for continuous OHS improvement and integration of risk management into daily operations, supporting safer, more sustainable growth in the renewable energy sector.

Keywords: Enamelling, Hazard, HIRARC, OHS.

INTRODUCTION

Fast-growing developments in industrialisation, mechanisation, electrification, and modernisation have increased the intensity and tempo of work in various industrial sectors. This has resulted in an increase in the physical and mental workload of workers, which can lead to fatigue, decreased concentration, and the risk of work accidents such as slipping, being pinched by machinery, or burns (Ramdan et al., 2022).

According to Government Regulation No. 50/2012, Occupational Safety and Health (OSH) aims to protect workers from the risk of occupational accidents and occupational diseases through hazard identification, risk assessment, and risk control.

The company is engaged in manufacturing renewable energy-based equipment, including solar water heaters. One of the critical processes in the production of a 150-litre

capacity solar water heater tank is the enamelling process, which involves the stages of degreasing, pickling, phosphating, enamel coating, oven and drying. Each of these stages has significant potential hazards, such as crane strikes, chemical skin irritation, burns, and ergonomic risks (Sari & Wibowo, 2023).

To identify and control these potential hazards, the Hazard Identification, Risk Assessment, and Risk Control (HIRARC) method is widely used in various industries. This method is effective in identifying hazards, assessing risk levels based on probability and impact, and designing appropriate control strategies. Previous research shows that the application of HIRARC can identify high risks in the production process and provide effective control recommendations, such as the use of personal protective equipment (PPE), occupational safety training, and improved standard operating procedures (Nugraha & Yuliasari, 2020; Pratiwi et al., 2021; Susanti et al., 2023).

Thus, the application of the HIRARC method in the solar water heater tank enamelling process in this company is expected to systematically identify potential hazards, assess the level of risk, and design effective controls to minimise the risk of occupational accidents and improve occupational safety and health in the company environment.

This study aims to: first, identify potential hazards that exist at each stage of the enamelling process of a 150 litre capacity solar water heater tank at PT Wijaya Karya Industri Energi. Second, assess the risk level of the identified hazards using the Hazard Identification, Risk Assessment and Risk Control (HIRARC) approach. Third, design appropriate risk control measures to minimise and/or eliminate the risk of work accidents based on the results of the HIRARC analysis. Fourth, provide recommendations for improving the occupational safety and health (OHS) system that is relevant and applicable in the enamelling process to create a safe and productive work environment.

RESEARCH METHOD

This study uses a qualitative descriptive approach with the Hazard Identification, Risk Assessment and Risk Control (HIRARC) method to identify and analyse potential hazards, assess risk levels, and provide risk control proposals in the enamelling process of solar water heater tanks at the Energy Conversion and Conservation Company.

The research was conducted in this company, specifically in the enamelling process of a solar water heater tank with a capacity of 150 litres. The research object includes all

stages of the process from degreasing, pickling, phosphating, coating (enamelling), oven, to drying.

The types and sources of data used consist of two, namely primary data obtained through direct observation, semi-structured interviews with workers and K3 staff, and documentation of production process activities. Secondary data obtained from internal company documents such as production SOPs, work accident reports, and OHS policies, as well as supporting scientific literature.

The steps of the HIRARC Method consist of three main stages, namely: hazard identification, risk assessment, and risk control. The hazard identification stage identifies all potential hazards at each stage of the work process. The risk assessment stage is to determine the level of risk based on two main parameters, namely likelihood and severity. The risks are classified into three levels: low, medium and high. The risk control stage is to determine control measures based on the principles of the risk control hierarchy: elimination, substitution, engineering, administration, and personal protective equipment (PPE).

Data analysis used is descriptive to describe potential hazards, risk levels, and proposed controls. HIRARC results are presented in the form of a risk matrix table and control recommendations.

RESULT AND DISCUSSION

Hazard Identification

A simple way to identify hazards is to make observations. Hazard identification is also revealed as the foundation of an accident prevention or risk control programme as shown in Table 1.

Tabel 1. Hazard Identfication

Activity	Source of Hazard	Risk
Tank	1. Crane 2. Tank	1. Crashed by crane 2. Bruises
Degreasing	1. Degreasing fluid 2. Crane 3. Residual soaking water	1. Stuck by a crane 2. Skin irritation 3. Slipped
Pickling	1. Pickling fluid 2. Crane 3. Residual soaking water	1. Stuck by a crane 2. Skin irritation 3. Burns 4. Slipped

Activity	Source of Hazard	Risk
Phosphating	1. Phosphating fluid 2. Crane 3. Residual soaking water	1. Stuck by a crane 2. Skin irritation 3. Slipped
Enamelling	1. Enamelling machine	1. Stuck by a machine 2. Fall from the ladder of the enamelling machine
Oven	1. Oven machine	1. Burns
Drying	1. Tank 2. Crane	1. Crushed by a tank 2. Crushed by a crane

Risk Assessment

Risk assessment that aims to assess the magnitude of the risk that may occur from each work process based on the identification of hazards that can occur. The risk assessment can be seen in Table 2.

Table 2. Risk Assessment

Activity	Hazard Identification	Risk Assessment		Risk Level
		Severity	Likehood	
Tank	Exposed to cranes due to not using proper PPE and in accordance with OHS standards.	3	3	*High*
	Operator hit by tank if not careful.	2	2	*Low*
Degreasing	Skin irritation due to exposure to degreasing fluid and not using proper PPE in accordance with OHS standards.	2	4	*High*
	Exposed to cranes due to not using proper PPE and in accordance with OHS standards.	3	3	*High*
	Slipped as a result of the remaining soaking water.	2	4	*High*
Pickling	Skin irritation or burns due to exposure to pickling liquid and not using good PPE and according to OHS standards.	3	4	*High*
	Exposed to cranes due to not using proper PPE and in accordance with OHS standards.	3	3	*High*

Activity	Hazard Identification	Risk Assessment		Risk Level
		Severity	Likehood	
	Slipped as a result of the remaining soaking water.	2	4	*High*
Phosphating	Skin irritation due to exposure to phosphating liquid and not using good PPE and according to OHS standards.	2	4	*High*
	Exposed to cranes due to not using proper PPE and in accordance with OHS standards.	3	3	*High*
	Slipped as a result of the remaining soaking water.	2	4	*High*
Enamelling	Being pinched by the enamelling machine and falling off the enamelling machine ladder resulted in injuries to the operator.	4	3	*Extreme*
Oven	The operator was burnt due to the operator not being careful when using the oven.	3	3	*High*
Drying	Operators are crushed by the tank if they are not careful.	2	2	*Low*
	Exposed to cranes due to not using proper PPE and in accordance with OHS standards.	3	3	*High*

Risk Control

Risk control is carried out on all hazards found in the hazard identification process and considers the risk rating to determine the priority and method of control. Risk control can be seen in Table 3.

Table 3. Risk Control

No	Activity	Potential Hazard	Potensial Risk	Risk Control
1.	The operator takes the tank to where the tank is degreased	Crane, Tank	Struck by a crane, Struck by a tank	It is necessary to conduct a briefing before carrying out work and wear complete personal protective equipment

No	Activity	Potential Hazard	Potensial Risk	Risk Control
				such as head protection and foot protection.
2.	The operator immerses the tank in a degreasing solution to remove grease and oil from the tank	Degreasing fluid, Crane, Residual soaking water	Struck by crane, Skin irritation, slipped	Operators are required to wear PPE such as protective clothing, head protection, hand protection, foot protection and position the place to avoid the danger of degreasing fluids and also to avoid slipping
3.	Operator immerses tank in pickling solution to remove rust on tank	Pickling liquid, Crane, Soaking residual water	Struck by a crane, Skin irritation, Skin burns, slips	Operators are required to wear PPE such as protective clothing, head protection, hand protection, foot protection and position the place to avoid the danger of pickling liquid and also to avoid slipping
4.	The operator soaks the tank in phosphating solution to open the pores on the tank surface for easy enamelling	Phosphating liquid, Crane, Residual soaking water	Struck by crane, Skin irritation, slipped	Operators must wear PPE such as protective clothing, head protection, hand protection, foot protection, positioning the place to avoid the danger of phosphating liquid and also to avoid slipping,
5.	Staining (enamelling) of the tank	Enamelling machine	Stuck by a machine Fall from the ladder of the enamelling machine	Operators must wear personal protective equipment such as head protection, hand protection, foot protection and must conduct a briefing before enamelling.
6.	The operator fires the tank in the oven	Oven machine	Burns	Operators must wear personal protective equipment such as protective clothing, head protection, hand protection, foot

No	Activity	Potential Hazard	Potensial Risk	Risk Control
				protection and must maintain the operator's position with the oven when the oven is switched on.
7.	The operator drains the tank	Tank, crane	Struck by a tank, Struck by a crane	Operators must wear personal protective equipment such as head protection, hand protection, foot protection and position themselves so that they are not crushed by the tank or crane.

Discussion

The enamelling process of a 150-litre solar water heater tank at the Energy Conversion and Conservation Company showed that of the 15 potential hazards identified, 13 were classified as High, 1 as Extreme, and only 1 as Low. These findings indicate that the level of occupational risk in the enamelling process is significant and needs to be seriously controlled.

The enamelling process of the 150-litre solar water heater tank at the Energy Conversion and Conservation Company showed that of the 15 potential hazards identified, 13 were classified as High, 1 as Extreme, and only 1 as Low. These findings indicate that the level of occupational risk in the enamelling process is significant and needs to be seriously controlled.

The most dominant risks stem from the inappropriate use of Personal Protective Equipment (PPE) by operators, lack of administrative controls such as regular briefings or training, mechanical hazard sources such as cranes and enamelling machines, and chemical exposure from pickling, phosphating and degreasing fluids.

These results are consistent with previous research which states that failure to use PPE is consistently the main cause of increased incidence of workplace accidents in the chemical manufacturing industry (Wibowo & Dewi, 2017). Similarly, another study found that the highest risk in the energy industry work environment comes from exposure to chemicals and mobile equipment such as cranes, especially if there is no written SOP and direct supervision (Utami et al., 2020).

The HIRARC method has proven to be an effective tool for evaluating potential hazards as it provides a systematic framework for identifying potential hazards based on actual work activities, assessing risks based on a combination of likelihood and severity, and determining the form of risk control based on the level of risk (Rizki & Tjahjono, 2018).

In the enamelling process, an extreme risk level (E) was found due to the danger of being pinched by the machine and falling from the stairs, with a severity value of 4 (severe injury) and a likelihood of 3 (occurs quite often). This is also in accordance with previous research which suggests that vertical work activities or in narrow areas tend to have extreme risks without additional security (Saputra et al., 2016).

The recommended control strategies include not only the use of PPE, but also engineering and administrative controls, such as the provision of safe work paths, periodic training, and regular risk evaluation. Past research confirmed that administrative controls integrated with technical interventions were shown to reduce the potential for accidents by 40% in the metal manufacturing sector (Yuliasari & Nugroho, 2019).

Thus, the application of the HIRARC method can not only be used to identify and evaluate risks, but also be the basis for planning a more comprehensive occupational safety management system, especially in the renewable energy industry which has a high complexity of production processes.

CONCLUSION

From the findings, it can be concluded that the enamelling process of the solar water heater tank has significant potential hazards, especially the risk of falling from the ladder and being pinched by the enamelling machine. The risk assessment shows a severity of 4 and a likelihood of 3, indicating that the risk is classified as extreme. To control the risk, operators are required to use complete personal protective equipment (PPE), such as head, hand and foot protection, and attend safety briefings before carrying out work. As a recommendation, improving the occupational safety and health system needs to be done through strict supervision of operator activities to create a safer and more controlled work environment.

REFERENCES

Nugraha, E. M., & Yuliasari, D. (2020). Penerapan Metode HIRARC dalam Identifikasi Bahaya dan Penilaian Risiko di Industri Manufaktur. *Jurnal Kesehatan Dan Keselamatan Kerja*, *12*(2), 89–95.

Pratiwi, R. A., Hidayat, T., & Lestari, N. (2021). Analisis Risiko K3 Menggunakan Metode HIRARC pada Proses Produks. *Jurnal Teknik Industri*, *15*(1), 30–37.

Ramdan, D., Siregar, A., & Fahmi, M. (2022). Dampak Beban Kerja dan Keselamatan Kerja terhadap Risiko Kecelakaan di Industri Berat. *Indonesian Journal of Occupational Safety*, *10*(3), 101–109.

Rizki, M. H., & Tjahjono, B. (2018). Penerapan HIRARC dalam Menilai Risiko pada Industri Manufaktur Skala Menengah. *Jurnal Teknik Industri*, *14*(1), 45–52.

Saputra, R. A., Cahyadi, T., & Listiani, D. (2016). Evaluasi Risiko Kecelakaan Kerja pada Proses Produksi Menggunakan Metode HIRARC. *Jurnal K3*, *5*(2), 85–92.

Sari, T. P., & Wibowo, R. (2023). Identifikasi Bahaya dan Penilaian Risiko Proses Kimia di Industri Energi Terbarukan. *Jurnal Energi Dan Lingkungan*, *8*(1), 55–62.

Susanti, Y., Rahmadani, A., & Gunawan, T. (2023). Penerapan HIRARC untuk Pengendalian Risiko Bahaya dalam Proses Produksi Logam. *Jurnal Keselamatan Kerja Terapan*, *11*(2), 120–129.

Utami, D. A., Hidayat, M., & Rachmawati, N. (2020). Analisis Bahaya Kerja dan Penilaian Risiko pada Industri Energi Berbasis Panel Surya. *Jurnal Keselamatan Dan Kesehatan Kerja*, *9*(3), 112–120.

Wibowo, A., & Dewi, S. (2017). Pengaruh Kepatuhan Penggunaan APD terhadap Tingkat Kecelakaan Kerja di Industri Kimia. *Indonesian Journal of Occupational Safety*, *6*(2), 76–83.

Yuliasari, D., & Nugroho, E. M. (2019). Strategi Pengendalian Risiko pada Proses Produksi Logam Menggunakan Pendekatan HIRARC. *Jurnal Teknik Dan Keselamatan Kerja*, *10*(1), 30–38.