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Identification and Control of Occupational Hazards in Recycled Paper Production Using the HIRADC Method

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Abstract
The recycled paper manufacturing industry involves various production stages that may expose workers to occupational hazards. This study aims to identify potential hazards, assess risk levels, and determine appropriate control measures in the production of recycled paper (Samson kraft) using the Hazard Identification, Risk Assessment, and Determining Control (HIRADC) method. Data were collected through direct observation, interviews with production workers and laboratory personnel, and documentation of production activities. Hazard identification was conducted in all production stages, including raw material storage and pressing, hydropulping, stock preparation, paper machine operations (wire part, press part, and dryer part), calendering, pope reel operations, and wastewater treatment. The results identified 24 potential hazards categorized as physical, mechanical, chemical, ergonomic, environmental, electrical, and biological hazards. Risk assessment indicated that Very High risks were concentrated in hydropulping, press part, dryer part, and calendering operations due to rotating machinery entrapment and exposure to high-temperature steam. High risks were associated with slippery floors, noise exposure, chemical handling, and material handling activities, while medium risks were mainly related to ergonomic strain and low-level chemical exposure. Evaluation of existing controls showed that risk mitigation measures were primarily based on administrative controls and personal protective equipment (PPE), whereas engineering controls remained limited in several critical areas. Residual risk assessment demonstrated that risk levels decreased after implementing proposed controls; however, several hazards remained at medium risk levels. Therefore, strengthening engineering controls, safety training, and safety culture is necessary to improve occupational safety performance in recycled paper manufacturing facilities.

Keywords: HIRADC, Occupational Safety And Health, Hazard, Recycled Paper, Samson Kraft.

1. Introduction

Paper is one of the most fundamental materials in modern society, widely used for administrative, commercial, packaging, and industrial purposes (Verma et al., 2021). Its versatility allows paper products to support a broad range of economic and industrial activities (Johansson et al., 2021). Although digital technologies have reduced paper consumption in certain sectors, paper remains essential for applications that require physical documentation and packaging (Berkhout & Hertin, 2004; Kirwan, 2012). Consequently, the paper industry continues to play a strategic role in supporting economic growth and industrial development.

The demand for paper products remains relatively stable due to their extensive use across various sectors (Järvinen et al., 2012). Many industries continue to depend on paper-based products to support operational, logistical, and commercial activities (Shen et al., 2014; Othen et al., 2025). In addition, paper products are essential components of packaging systems that facilitate the distribution of goods (Opara, 2013). This continued demand demonstrates the importance of maintaining a productive and sustainable paper manufacturing sector.

In Indonesia, the paper industry is recognized as one of the most important industrial sectors because it absorbs a significant number of workers and supplies products required by numerous downstream industries (Van Dijk & Bell, 2007; Ahmad et al., 2018). The industry contributes not only to national economic development but also to the continuity of manufacturing and commercial activities. Its strategic role highlights the need for efficient production systems and sustainable industrial practices to ensure long-term competitiveness and productivity (Kristaufan et al., 2010).

The recycled paper industry plays a crucial role in sustainability efforts by transforming used paper and cardboard into new products such as Samson kraft paper. Through recycling activities, waste materials can be reintroduced into the production cycle, reducing environmental burdens associated with paper waste disposal. This practice supports resource conservation while maintaining the availability of paper products for industrial applications. As environmental concerns continue to grow, recycled paper production has become an increasingly important component of sustainable manufacturing.

The production of recycled paper involves a series of interconnected processes that convert used paper materials into finished products. These processes generally include raw material pressing, hydropulping, paper machine operations, calendering, and winding. Each stage serves a specific function in ensuring that recycled fibers can be processed into paper products with the required quality standards. The successful operation of each stage is therefore essential to maintaining production efficiency and product consistency.

The implementation of these production activities requires the use of industrial machinery, chemical agents, high temperatures, and physical labor. While these elements are necessary to achieve production objectives, they also create occupational safety and health (OSH) challenges within the workplace. Workers are frequently required to interact with machinery, chemicals, and demanding working environments throughout the production process. Consequently, effective safety management is necessary to minimize potential risks and ensure safe working conditions (Sukma Rani, 2018).

Workers in recycled paper manufacturing facilities are exposed to a variety of workplace hazards that may affect their health and safety. Mechanical hazards associated with moving machinery may result in entrapment injuries, while excessive noise exposure can contribute to hearing impairment. In addition, workers may be exposed to high temperatures, steam, and chemical substances used during production activities. These hazards represent significant occupational risks that require appropriate preventive measures.

Ergonomic hazards are also present due to repetitive manual handling activities and physically demanding tasks performed during production operations. Prolonged exposure to such conditions may increase the likelihood of musculoskeletal disorders, fatigue, and reduced worker performance. Without proper hazard identification and systematic risk management, these workplace conditions may result in serious occupational accidents and diseases. Therefore, industries must adopt proactive approaches to identify and control hazards before incidents occur (Rahadi et al., 2018).

One of the most widely applied methods in occupational safety management is the Hazard Identification, Risk Assessment, and Determining Control (HIRADC) method (Shamsuddin et al., 2014; Henny et al., 2025). This method provides a systematic framework for identifying workplace hazards, evaluating the associated risks, and determining appropriate control measures. Through a structured assessment process, organizations can prioritize hazards according to their severity and likelihood of occurrence. The implementation of HIRADC enables industries to proactively address safety concerns and establish effective preventive strategies to reduce occupational risks (Tarwaka, 2014).

Based on these considerations, this study aims to identify potential occupational hazards in a recycled paper production facility using the HIRADC method. The identification process covers each production stage, beginning from raw material intake and continuing through to the final paper roll product. Through a comprehensive assessment of workplace hazards, this study seeks to provide a clearer understanding of occupational risks within recycled paper manufacturing operations. The findings are expected to serve as a practical reference for improving OSH conditions and supporting systematic risk management in the recycled paper manufacturing industry (Ajeng & Sinta, 2024).

2. Research Methods

2.1 Research Approach

This study used a descriptive observational approach to identify potential occupational hazards in the recycled paper production process. Data were obtained through direct observation of work activities and structured interviews with production workers and laboratory personnel. This approach was used to document working conditions and identify potential hazards at each stage of the production process.

2.2 Study Location and Object

The study was conducted at a recycled paper manufacturing plant located in the Sapan Industrial Area, Bandung Regency, West Java, Indonesia. The facility operates a continuous production system and produces Samson kraft paper from used paper and cardboard as primary raw materials. The field visit was conducted on December 26, 2023.

2.3 Data Collection

The data collected in this study include:

a. Primary Data

Primary data were collected through direct observation of the production process, interviews with workers and the laboratory head, and documentation of work activities and equipment conditions.

b. Secondary Data

Secondary data were obtained from company operational records, standard operating procedures (SOPs), and published literature related to occupational safety in the paper manufacturing industry.

2.4 Risk Analysis Method

Risk analysis was conducted using the HIRADC (Hazard Identification, Risk Assessment, and Determining Controls) method, which provides a systematic approach to identify hazards, evaluate risks, and implement control measures (Ajeng & Sinta, 2024). The following sequential steps were applied:

a. Hazard Identification

Hazard identification is a systematic process used to recognize and evaluate potential sources of danger in the workplace. In the context of a paper manufacturing facility, hazards were identified based on the following categories:

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- Physical Hazard: risks from heat, noise, vibration, slippery floors, and sharp or moving objects.
- Chemical Hazard: risks from exposure to aluminum sulfate ($Al_2(SO_4)_3$), tapioca-based chemical additives, and other processing agents.
- Electrical Hazard: risks from damaged cables, wet electrical installations, or improper grounding of industrial equipment.
- Mechanical Hazard: risks from rotating machine components including hydropulpers, paper machine rolls, and calender rolls.
- Ergonomic Hazard: risks from manual handling, repetitive movements, and prolonged awkward postures.
- Environmental Hazard: risks from steam accumulation, poor ventilation, noise levels, and wastewater exposure in the production area.
- Biological Hazard: risks from microbial contamination in water-based processes and wastewater treatment areas.

b. Risk Assessment

Risk assessment was performed by evaluating the level of risk associated with each identified hazard using the parameters of likelihood and severity, as shown in Table 1 and Table 2.

Table 1. Likelihood Parameter

Level	Likelihood Scale	Description
1	Rare	Highly unlikely to occur; may only happen in exceptional circumstances (e.g., once in 10 years).
2	Unlikely	Could occur at some time, but the probability is low.
3	Possible	Might occur at some time; exposure to the hazard is periodic.
4	Likely	Will probably occur in most circumstances; frequent exposure recorded.
5	Almost Certain	Expected to occur in most circumstances; high probability due to lack of adequate controls.

Table 2. Severity Parameter

Level	Severity Scale	Description
1	Insignificant	Requires only minor first aid; no lost work time.
2	Minor	Minor injury requiring medical treatment; lost work time < 2 days.
3	Moderate	Moderate injury or temporary disability; lost work time 2–14 days.
4	Major	Partial permanent disability or severe occupational disease; significant material loss.
5	Catastrophic	Fatality, total permanent disability, or massive environmental damage.

Table 3. Risk Matrix

SEVERITY / LIKELIHOOD		1	2	3	4	5
S	5	5 Med	10 High	15 High	20 V.High	25 V.High
S	4	4 Low	8 Med	12 High	16 High	20 V.High
S	3	3 Low	6 Med	9 Med	12 High	15 High
S	2	2 Low	4 Low	6 Med	8 Med	10 High
S	1	1 Low	2 Low	3 Low	4 Low	5 Med

c. Risk Controls

Risk control was established according to the assessed risk level by referring to the hierarchy of controls: elimination, substitution, engineering controls, administrative controls, and personal protective equipment (PPE). Control measures were prioritized from the most effective to the least effective in order to minimize the probability and impact of identified hazards (Ramli, 2010).

d. Monitoring and Review

Monitoring and review were conducted through regular inspections to evaluate the effectiveness of implemented control measures, ensure compliance with safety procedures, and support continuous improvement in the safety and efficiency of the production process (OHSAS 18001, 2007).

2.5 Research Procedure

The study was carried out through systematic stages, including literature review, field observation, problem identification, data collection and processing, hazard analysis, and conclusion formulation. The HIRADC framework was applied at each production stage to ensure comprehensive coverage of all potential hazards.

3. Results and Discussions

3.1 Process Description of Recycled Paper Production

The production of Samson kraft recycled paper begins with the intake of used paper (OCC — Old Corrugated Containers) and cardboard waste as primary raw materials. The production system operates continuously. The main production stages are as follows:

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- Raw Material Storage and Pressing: Incoming waste paper and cardboard are stored and subsequently compressed using a mechanical pressing machine with a capacity of 500 kg per press cycle. This step reduces material volume and facilitates handling.
- Hydropulping: The pressed raw material is fed into a hydropulper where it is mixed with water to break down the fibers and produce paper pulp (slurry). This stage is critical for fiber separation.
- Stock Preparation and Mixing: The pulp is refined and blended with chemical additives including tapioca (as a binder) and aluminum sulfate ($Al_2(SO_4)_3$) as a coagulant to achieve the desired consistency (approximately 4% mixing concentration).
- Paper Machine Line (PM 1, PM 2, PM 3): The prepared stock is fed into the headbox of the paper machines. PM 1 and PM 3 use open headboxes, while PM 2 uses a closed headbox with a pressure blower. The paper machine line consists of three sequential sub-stages: (1) Wire Part — sheet formation on the wire mesh, reducing water content by approximately 80%; (2) Press Part — mechanical pressing to further remove water (approximately 35% water reduction); and (3) Dryer Part — final drying using steam distributed from a boiler.
- Calendering: The dried paper sheet passes through calender rolls to smooth and equalize the thickness of the paper web.
- Pope Reel: The finished paper is wound into rolls with specified grammage (70 gsm or 80 gsm depending on customer requirements). Each finished roll measures 2.5 tons with a width of 2.4 meters. Total daily roll output is approximately 43.88 rolls.

The primary product is Samson kraft paper sold in roll form to other industries. Wastewater generated during the process is treated through the Wastewater Treatment Plant (IPAL) before discharge to meet government quality standards.

3.2 Identified Hazards

The identified hazards were classified based on observed work activities and workplace conditions at each production stage. Table 4 presents a comprehensive list of potential hazards and their expected impacts.

Table 4. Potential Hazards in Recycled Paper Production

Work Activity	Hazard Category	Potential Hazard	Potential Impact
Raw Material Storage & Pressing	Physical hazard	Falling bales of compressed paper/cardboard	Crush injury, fractures, or fatal trauma
Raw Material Storage & Pressing	Ergonomic hazard	Manual handling of heavy raw material bales	Back pain, muscle strain, and musculoskeletal disorders
Raw Material Storage & Pressing	Mechanical hazard	Contact with hydraulic pressing mechanism	Finger/hand entrapment, crush injury
Hydropulping	Mechanical hazard	Contact with rotating hydropulper rotor	Severe laceration, hand entrapment, or fatal injury
Hydropulping	Physical hazard	Wet and slippery floor from water spillage	Slipping, falling, bruises, or head injury
Hydropulping	Chemical hazard	Exposure to process water containing residual chemicals	Skin irritation or eye irritation
Stock Preparation & Mixing	Chemical hazard	Exposure to aluminum sulfate ($Al_2(SO_4)_3$) dust or solution	Skin irritation, eye damage, and respiratory irritation
Stock Preparation & Mixing	Ergonomic hazard	Manual mixing and repetitive stirring operations	Shoulder pain, wrist strain, and fatigue
Wire Part (Wet End)	Physical hazard	Wet and slippery working surface	Slipping and falling accidents
Wire Part (Wet End)	Mechanical hazard	Contact with forming wire mesh or roll nip points	Hand/finger entrapment, laceration
Press Part	Mechanical hazard	Entrapment in nip between press rolls	Severe crush injury, fracture, or amputation
Press Part	Physical hazard	Vibration from high-speed roll operations	Hand-arm vibration syndrome, fatigue
Dryer Part	Physical hazard	Exposure to high-temperature steam from dryer cylinders	Burns, heat stress, and dehydration
Dryer Part	Physical hazard	Contact with hot dryer cylinder surfaces	Severe skin burns
Dryer Part	Environmental hazard	Steam accumulation and poor ventilation in dryer section	Heat exhaustion, reduced visibility, and increased accident risk

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Dryer Part	Electrical hazard	Wet conditions near electrical panels and steam connections	Electric shock or electrocution
Calendering	Mechanical hazard	Entrapment in calender roll nip	Crush injury, fracture, or degloving
Calendering	Physical hazard	Noise from high-speed calender rolls	Hearing discomfort and hearing impairment
Pope Reel (Winding)	Mechanical hazard	Entrapment in winding roll mechanism	Hand/arm entrapment and severe injury
Pope Reel (Winding)	Ergonomic hazard	Manual guidance of paper web during reel change	Strain injury, fatigue
Pope Reel (Winding)	Physical hazard	Falling finished roll during transfer or storage	Crush injury or fatal trauma
General (All Stages)	Physical hazard	High ambient noise levels from all machine operations	Chronic hearing impairment (noise-induced)
General (All Stages)	Environmental hazard	Dust from paper fiber and process materials	Respiratory irritation and chronic lung disease
IPAL Operation	Chemical hazard	Exposure to coagulation chemicals (polymer, alum) and wastewater	Skin/eye irritation, chemical burns
IPAL Operation	Biological hazard	Contact with biologically active wastewater in aeration basins	Skin infection, gastroenteric illness

3.3 Risk Assessment Results

The hazards identified in the previous section were evaluated for their risk levels based on likelihood (L) and severity (S). The risk score (R = L × S) and corresponding risk level were determined using the risk matrix in Table 3. Assessment was based on field observations and interviews with workers.

Table 5. Risk Assessment Results

Work Activity	**Potential Hazard**	**Potential Impact**	**L**	**S**	**R**	**Risk Level**
Raw Material Storage & Pressing	Falling bales of compressed paper/cardboard	Crush injury, fractures, or fatal trauma	3	5	15	High
Raw Material Storage & Pressing	Manual handling of heavy raw material bales	Back pain, muscle strain, and musculoskeletal disorders	4	2	8	Medium
Raw Material Storage & Pressing	Contact with hydraulic pressing mechanism	Finger/hand entrapment, crush injury	3	4	12	High
Hydropulping	Contact with rotating hydropulper rotor	Severe laceration, hand entrapment, or fatal injury	4	5	20	Very High
Hydropulping	Wet and slippery floor from water spillage	Slipping, falling, bruises, or head injury	5	2	10	High
Hydropulping	Exposure to process water containing residual chemicals	Skin irritation or eye irritation	3	2	6	Medium
Stock Preparation & Mixing	Exposure to aluminum sulfate dust or solution	Skin irritation, eye damage, and respiratory irritation	4	3	12	High
Stock Preparation & Mixing	Manual mixing and repetitive stirring operations	Shoulder pain, wrist strain, and fatigue	4	2	8	Medium
Wire Part (Wet End)	Wet and slippery working surface	Slipping and falling accidents	5	2	10	High
Wire Part (Wet End)	Contact with forming wire mesh or roll nip points	Hand/finger entrapment, laceration	4	4	16	High
Press Part	Entrapment in nip between press rolls	Severe crush injury, fracture, or amputation	4	5	20	Very High
Press Part	Vibration from high-speed roll operations	Hand-arm vibration syndrome, fatigue	4	2	8	Medium
Dryer Part	Exposure to high-temperature steam from dryer cylinders	Burns, heat stress, and dehydration	5	4	20	Very High
Dryer Part	Contact with hot dryer cylinder surfaces	Severe skin burns	4	4	16	High

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Dryer Part	Steam accumulation and poor ventilation	Heat exhaustion, reduced visibility, accident risk	5	2	10	**High**
Dryer Part	Wet conditions near electrical panels	Electric shock or electrocution	3	5	15	**High**
Calendering	Entrapment in calender roll nip	Crush injury, fracture, or degloving	4	5	20	**Very High**
Calendering	Noise from high-speed calender rolls	Hearing discomfort and hearing impairment	5	3	15	**High**
Pope Reel (Winding)	Entrapment in winding roll mechanism	Hand/arm entrapment and severe injury	4	4	16	**High**
Pope Reel (Winding)	Falling finished roll during transfer or storage	Crush injury or fatal trauma	3	5	15	**High**
General (All Stages)	High ambient noise levels from all machine operations	Chronic hearing impairment (noise-induced)	5	3	15	**High**
General (All Stages)	Dust from paper fiber and process materials	Respiratory irritation and chronic lung disease	4	3	12	**High**
IPAL Operation	Exposure to coagulation chemicals (polymer, alum)	Skin/eye irritation, chemical burns	3	3	9	**Medium**
IPAL Operation	Contact with biologically active wastewater	Skin infection, gastroenteric illness	3	2	6	**Medium**

Based on the results in Table 5, Very High risks were identified in the hydropulping, press part, dryer part, and calendering stages, primarily involving fatal entrapment by high-speed rotating machinery and severe burns from steam exposure. High risks are widespread across all stages, particularly related to slippery floors, noise, chemical exposure, and falling finished rolls. Medium risks were found in ergonomic strain and chemical exposure at lower-intensity stages. These findings underscore the critical need for robust engineering controls and PPE at multiple production points.

The prioritization of these risk levels is based on the combination of likelihood and severity values within the HIRADC risk matrix, which enables systematic classification of hazards according to their potential impact on worker safety. Very High risk activities are characterized by both high severity outcomes, including fatality or permanent disability, and relatively high exposure probability due to continuous interaction between workers and high-speed mechanical equipment. These conditions are predominantly found in hydropulping, press, dryer, and calendering operations, where rotating machinery and thermal energy sources present significant occupational hazards.

In comparison, High risk categories are largely associated with environmental and physical conditions that occur frequently during routine operations, such as wet and slippery floors, elevated noise levels, exposure to chemical agents, and handling of heavy finished rolls. Although these hazards may have lower severity compared to mechanical entrapment risks, their high likelihood of occurrence contributes significantly to overall workplace risk levels. This indicates that operational conditions and housekeeping practices play an important role in influencing accident probability across all production stages.

Meanwhile, Medium risk hazards are primarily related to ergonomic stress and lower-intensity chemical exposure, which generally result in non-fatal but potentially long-term occupational health effects. If not properly managed, these risks may develop into chronic conditions such as musculoskeletal disorders or mild respiratory irritation. Therefore, although categorized as lower priority compared to mechanical hazards, these risks still require preventive attention through administrative controls and ergonomic improvements.

Overall, the risk distribution highlights that occupational safety management in recycled paper production should prioritize engineering controls for high-severity mechanical hazards, while simultaneously maintaining administrative and PPE-based controls for environmental, physical, and ergonomic risks to ensure comprehensive risk mitigation across all operational areas.

3.4 Risk Control Measures

Based on the hazard identification and risk assessment results, the following risk control measures were identified, including existing controls and recommended additional actions for each production stage.

Table 6. Risk Control Measures

Work Activity	Potential Hazard	Potential Impact	Existing Control	Recommended Action
Raw Material Storage & Pressing	Falling bales of compressed paper/cardboard	Crush injury, fractures, or fatal trauma	Bales stacked manually by workers	Install stacking height limits and mandatory helmet/safety shoe use

Raw Material Storage & Pressing	Manual handling of heavy raw material bales	Back pain, muscle strain	Manual lifting by workers	Provide mechanical lifting aids and train workers in safe lifting techniques
Raw Material Storage & Pressing	Contact with hydraulic pressing mechanism	Finger/hand entrapment, crush injury	Operated by experienced workers	Install machine guards and emergency stop systems
Hydropulping	Contact with rotating hydropulper rotor	Severe laceration, fatal injury	Operator maintains distance	Install fixed machine guards and interlock safety systems; mandatory PPE
Hydropulping	Wet and slippery floor from water spillage	Slipping, falling, head injury	Manual floor cleaning	Install anti-slip flooring and drainage channels; require safety boots
Hydropulping	Exposure to residual chemicals in process water	Skin/eye irritation	No specific control observed	Provide rubber gloves and eye protection; install eyewash stations
Stock Preparation & Mixing	Exposure to aluminum sulfate dust or solution	Skin irritation, eye damage, respiratory irritation	Workers handle chemicals manually	Mandatory PPE (gloves, goggles, dust mask); enclosed chemical dosing system
Stock Preparation & Mixing	Manual mixing and repetitive stirring	Shoulder pain, wrist strain	Workers rest when tired	Provide ergonomic mixing tools; implement scheduled rest breaks
Wire Part (Wet End)	Wet and slippery working surface	Slipping and falling accidents	Manual floor cleaning	Install anti-slip mats; implement wet floor warning signs
Wire Part (Wet End)	Contact with forming wire or roll nip points	Hand/finger entrapment, laceration	Guarding on major nip points	Inspect all nip guards regularly; enforce no-touching-wire-in-motion rule
Press Part	Entrapment in nip between press rolls	Severe crush injury, amputation	Safety barriers in place	Mandatory nip guards; implement lock-out/tag-out (LOTO) procedures
Press Part	Vibration from high-speed roll operations	Vibration syndrome, fatigue	No specific control observed	Provide vibration-dampening gloves; limit continuous exposure time
Dryer Part	Exposure to high-temperature steam	Burns, heat stress, dehydration	Workers maintain distance from dryer	Mandatory heat-resistant gloves; improve ventilation; mandatory hydration breaks
Dryer Part	Contact with hot dryer cylinder surfaces	Severe skin burns	Workers cautioned verbally	Install thermal insulation on accessible cylinder surfaces; mandatory PPE
Dryer Part	Steam accumulation and poor ventilation	Heat exhaustion, reduced visibility	Natural ventilation in building	Install industrial exhaust fans; mandatory heat-stress monitoring
Dryer Part	Wet conditions near electrical panels	Electric shock, electrocution	Basic inspection by workers	Install waterproof electrical enclosures; mandatory routine electrical inspection
Calendering	Entrapment in calender roll nip	Crush injury, degloving	Guarding on nip points	Full nip guard installation; LOTO procedures; emergency stop accessible
Calendering	Noise from high-speed calender rolls	Hearing impairment	No hearing protection observed	Mandatory earplugs/earmuffs; conduct regular audiometric testing
Pope Reel (Winding)	Entrapment in winding roll mechanism	Hand/arm severe injury	Barriers in place	Improve guarding; LOTO during reel change; mandatory PPE

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Pope Reel (Winding)	Falling finished roll during transfer	Crush injury, fatal trauma	Workers manually guide rolls	Use mechanical roll handling equipment; demarcate exclusion zones
General (All Stages)	High ambient noise levels	Chronic hearing impairment	No systematic protection	Mandatory hearing protection program; implement noise reduction at source
General (All Stages)	Dust from paper fiber	Respiratory irritation, chronic lung disease	Open building structure	Provide dust masks (N95); install dust collection systems
IPAL Operation	Exposure to coagulation chemicals	Skin/eye irritation, chemical burns	Workers handle with care	Provide gloves, goggles, and aprons; post chemical handling SOP
IPAL Operation	Contact with biologically active wastewater	Skin infection, gastroenteric illness	No specific control observed	Provide waterproof gloves and boots; prohibit eating in IPAL area

Based on the risk assessment, Very High risks identified at the hydropulping, press part, dryer part, and calendering stages require immediate priority intervention. Engineering controls such as machine guarding, lock-out/tag-out systems, and thermal insulation must be implemented alongside mandatory PPE programs. High risks related to noise and slippery floors require facility-wide interventions including anti-slip flooring, hearing protection programs, and systematic housekeeping. Medium risks from ergonomic strain and chemical handling can be effectively addressed through administrative controls and ergonomic tool provision.

To evaluate the effectiveness of these control measures, a residual risk assessment was conducted to determine the remaining level of risk after implementation of proposed interventions. The results of this evaluation are presented in Table 7, which compares the initial risk levels with the corresponding residual risk levels after application of engineering, administrative, and personal protective controls.

Tabel 7. Residual Risk Assessment Result

Work Activity	**Potential Hazard**	**Initial Risk (R/Level)**	**Control Measures**	**Residual Risk (R/level)**
Raw Material Storage & Pressing	Falling bales of compressed paper/cardboard	15 – High	Stack height limit, helmet & safety shoes	8 – Medium
Raw Material Storage & Pressing	Manual handling of heavy raw material bales	8 – Medium	Mechanical lifting aids, training	4 – Low
Raw Material Storage & Pressing	Contact with hydraulic pressing mechanism	12 – High	Machine guard, emergency stop	6 – Medium
Hydropulping	Contact with rotating hydropulper rotor	20 – Very High	Fixed guard, interlock system, PPE	10 – High
Hydropulping	Wet and slippery floor from water spillage	10 – High	Anti-slip flooring, drainage	5 – Medium
Hydropulping	Exposure to residual chemicals in process water	6 – Medium	PPE (gloves, goggles), eyewash station	3 – Low
Stock Preparation & Mixing	Exposure to aluminum sulfate dust or solution	12 – High	Enclosed dosing system, PPE	6 – Medium
Stock Preparation & Mixing	Manual mixing and repetitive stirring	8 – Medium	Ergonomic tools, rest breaks	4 – Low
Wire Part (Wet End)	Wet and slippery working surface	10 – High	Anti-slip mats, warning signs	5 – Medium
Wire Part (Wet End)	Contact with forming wire or roll nip points	16 – High	Guarding + safety rule enforcement	8 – Medium
Press Part	Entrapment in nip between press rolls	20 – Very High	LOTO system, full guarding	10 – High

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Press Part	Vibration from high-speed roll operations	8 – Medium	Anti-vibration gloves, exposure limit	4 – Low
Dryer Part	Exposure to high-temperature steam	20 – Very High	Insulation, PPE, ventilation	10 – Highventilation; mandatory hydration breaks
Dryer Part	Contact with hot dryer cylinder surfaces	16 – High	Thermal insulation, PPE	8 – Medium
Dryer Part	Steam accumulation and poor ventilation	10 – High	Exhaust fan, heat monitoring	5 – Medium
Dryer Part	Wet conditions near electrical panels	15 – High	Waterproof enclosure, inspection	6 – Medium
Calendering	Entrapment in calender roll nip	20 – Very High	LOTO + full guarding	10 – High
Calendering	Noise from high-speed calender rolls	15 – High	Ear protection program	8 – Medium
Pope Reel (Winding)	Entrapment in winding roll mechanism	16 – High	Guarding + LOTO	8 – Medium
Pope Reel (Winding)	Falling finished roll during transfer	15 – High	Mechanical handling tools	8 – Medium
General (All Stages)	High ambient noise levels	15 – High	Hearing protection program	8 – Medium
General (All Stages)	Dust from paper fiber	12 – High	N95 mask + dust collector	6 – Medium
IPAL Operation	Exposure to coagulation chemicals	9 – Medium	PPE + SOP handling	4 – Low
IPAL Operation	Contact with biologically active wastewater	6 – Medium	Gloves, boots, hygiene control	3 – Low

3.5 Comparative Analysis of OSH Conditions in Recycled Paper Production and Conventional Paper Industry

The following analysis compares the OSH conditions observed in this recycled paper production facility with published findings from conventional paper and pulp manufacturing industries. In conventional virgin pulp-based mills, chemical hazards from chlorine-based bleaching agents, caustic soda, and sulfur compounds present significant health risks, whereas in recycled paper plants, chemical hazards are comparatively reduced but not eliminated, as aluminum sulfate and polymer coagulants are still used in both production and wastewater treatment (ILO, 2011).

Mechanical hazards in both types of plants are similarly critical, as high-speed paper machine rolls present universal entrapment risks. However, the scale of continuous operations in modern large-scale mills typically involves more comprehensive machine guarding and automated safety systems, whereas smaller-scale recycled paper facilities may rely more on administrative controls and worker experience (Rahadi et al., 2018). Noise exposure is a shared challenge across both facility types, with levels frequently exceeding 85 dB(A) in machine rooms and dryer sections, necessitating comprehensive hearing conservation programs in both contexts (Viatina et al., 2024).

The recycled paper production process introduces additional hazards specific to raw material handling, including the risk of falling bales during pressing operations and pathogen exposure from contaminated waste paper. These hazards are absent in virgin-fiber mills. Conversely, the wastewater treatment operations in both types of facilities present similar biological and chemical risks, although the volume and composition of wastewater differ. Overall, while the risk profile of recycled paper production differs from conventional mills in specific hazard types, the fundamental importance of systematic HIRADC-based hazard management applies equally to both (Ajeng & Sinta, 2024).

Building upon this comparison, the evaluation of existing control measures indicates that most implemented risk controls in the observed facility are still predominantly administrative in nature or rely heavily on personal protective equipment (PPE). This suggests that hazard mitigation has not been fully addressed at the source, particularly in high-risk processes such as hydropulping, press section, dryer section, and calendering operations. According to the hierarchy of controls, this approach represents a less effective risk reduction strategy compared

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to engineering-based interventions such as isolation, automation, and machine guarding, as emphasized in occupational risk management principles (Ramli, 2010).
Therefore, further improvement is required through the implementation of more robust engineering controls, including fixed machine guarding, interlock safety systems, lock-out/tag-out (LOTO) procedures, and thermal insulation on high-temperature equipment. These measures are expected to significantly reduce direct worker exposure to hazardous energy sources and minimize the likelihood of severe occupational accidents.
In addition, human factors play a significant role in shaping the overall risk profile identified in this study. Worker behavior, adherence to standard operating procedures (SOPs), and consistency in the use of personal protective equipment strongly influence the effectiveness of existing safety measures. This finding is consistent with previous studies emphasizing that the development of a strong safety culture is essential in reducing occupational incidents in manufacturing environments (Tarwaka, 2014), (ILO, 2011). Consequently, continuous safety training, supervision, and reinforcement of safe work practices are necessary to improve compliance and awareness among workers.
Finally, this study does not include a quantitative evaluation of residual risk following the implementation of control measures. As a result, the actual effectiveness of the proposed controls in reducing risk levels cannot be fully measured. Future studies are recommended to incorporate before-and-after risk assessments to quantify the reduction in risk more accurately. The use of quantitative measurement tools such as sound level meters for noise exposure and heat stress indices for thermal environments is also suggested to enhance the validity and robustness of future HIRADC-based studies (OHSAS 18001, 2007).
Finally, while the implementation of control measures has significantly improved occupational safety conditions in the observed facility, a residual level of risk is still present in several production areas. Engineering controls such as machine guarding, interlock systems, and lock-out/tag-out (LOTO) procedures are expected to reduce the likelihood of severe mechanical injuries; however, these risks cannot be fully eliminated due to the inherent nature of high-speed industrial operations. As a result, hazards in hydropulping, press, dryer, and calendering sections may still persist at a medium risk level even after control implementation.
Similarly, physical and environmental hazards such as noise exposure, slippery surfaces, and heat stress may experience risk reduction when administrative controls and personal protective equipment (PPE) are properly applied. Nevertheless, the effectiveness of these measures remains highly dependent on worker compliance and continuous supervision. This indicates that residual risk is not only influenced by technical control measures but also by human factors and safety culture within the workplace.
Therefore, although the proposed control strategies significantly reduce initial risk levels, continuous monitoring, periodic evaluation, and strengthening of occupational safety practices are still required to ensure sustained risk reduction in recycled paper production facilities.

4. Conclusion

This study identified a comprehensive range of occupational hazards in the recycled paper (Samson kraft) production process using the HIRADC method. A total of 24 hazards were identified across eight production stages, including raw material pressing, hydropulping, stock preparation, wire part, press part, dryer part, calendering, and pope reel operations, as well as wastewater treatment activities.
Very High risks were identified in four critical stages: hydropulping (rotating rotor contact), press part (nip roll entrapment), dryer part (steam exposure), and calendering (calender nip entrapment). These hazards require immediate implementation of engineering controls including machine guarding, lock-out/tag-out procedures, thermal insulation, and interlock safety systems. High risks associated with slippery floors, noise, falling finished rolls, and chemical exposure were identified across all stages, necessitating facility-wide preventive programs.
The application of the HIRADC method proved effective in systematically uncovering the diverse risk landscape of recycled paper manufacturing. The findings provide a practical basis for prioritizing safety investments and improving occupational health and safety management in similar industrial settings. Continuous monitoring, worker safety training, and periodic HIRADC reviews are strongly recommended to sustain improvement and prevent workplace accidents.

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