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Hazard Identification Using Task Risk Assessment Method and Bowtie Analysis (Case Study: PT. Varia Usaha Beton)

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Abstract. PT. Varia Usaha Beton is a subsidiary of PT. Semen Indonesia Beton, which produces various types of products. PT Varia Usaha Beton (BSP Purwokerto) has an open work area where there are potential hazards such as physical factors, chemical factors and ergonomic factors. The aim of this research is to identify hazards, assess risks and control risks in the production process of ready-mixed concrete so that workplace accidents can be minimized. The methods used in this research are task risk assessment and bowtie analysis. Based on the research results, it was found that 1 risk belonged to the low category, 27 risks belonged to the medium category, and 11 risks belonged to the high category. Based on the bow-tie method, the major risks are exposure to fly ash and cement dust, risk of diesel spills, and risk of electric shock. The main causes of workplace accidents are pipe leaks and improper diesel filling. The main risk effects of workplace accidents are worker injury, and fire. The bowtie analysis method determines that the risk of electric shock is due to a damaged cable and the existing protective barrier is intended to replace the damaged cable. This risk has consequences, namely injuries to workers.

Keyword: Bowtie Analysis, Hazard Identification, Ready-Mixed Concrete, Task Risk Assessment

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1. Introduction

Every job has potential dangers. If potential hazards are not addressed and controlled, they can potentially lead to fatigue, musculoskeletal problems, injuries, and possibly even occupational accidents [1]. The International Labor Organization (ILO) states that there are 1.1 million deaths every year due to occupational diseases or accidents [2]. Occupational accidents can be avoided by knowing and recognizing the various potential hazards in the work environment [3]. Therefore, it is necessary to control hazards by identifying and then identifying potential hazards in the work area. Danger is any situation or action that has the potential to cause accidents or injuries to people, damage to machinery, or other disruptions [4]. Occupational safety and health (K3) are conditions and factors that affect or may affect the health and safety of workers in the workplace

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(OHSAS 18001:2007, 2007). The implementation of occupational safety and health protection (K3) is very important, especially in companies with direct contact with the construction industry, so that employees can feel safe, comfortable, healthy and secure [5]. According to Restuputri & Sari (2015), to reduce or eliminate hazards that may lead to workplace accidents, risk management activities are required, including hazard identification, potential hazard analysis, risk assessment, risk control, and monitoring and evaluation [6]. By implementing K3, we can prevent accidents, damage or illnesses caused by accidents at work and thus save costs that could arise from accidents [7]. The occupational safety and health management system (SMK3) is part of the company's overall management system in the context of controlling risks related to work activities in order to create a safe, efficient and productive workplace [8]. According to the Decree of the Minister of Manpower and Transmigration RI No. 609 of 2012 on Settlement Guidelines and Occupational Diseases, industrial accidents are accidents that occur in the context of industrial relations. An employment relationship can mean that an accident occurs due to work-related reasons or while carrying out work [9].

PT Varia Usaha Beton (BSP Purwokerto) has an open work area where potential hazards such as physical factors, namely noise, chemical factors including the form of solids, liquid particles, gas, mist, aerosol, etc. exist vapor, while the ergonomic factors that occur, namely there is a mismatch between the worker and the tools or equipment used in the work. Furthermore, workers' lack of understanding of the recognition of hazards that may occur during work performance may be one of the main factors responsible for the high number of occupational accidents in construction projects [10]. Therefore, it is necessary to identify hazards, conduct a risk analysis and control the potential hazards.

One of the methods used in this research is the Task Risk Assessment (TRA) method. Task Risk Assessment (TRA) is a hazard identification method carried out to find out what and how great are the potential hazards encountered during activities in order to prevent occupational accidents and control these hazards [11]. This method is useful for identifying dangerous risks related to work or a task. Risk is an impact that can have both positive and negative effects on the project due to the uncertainty that occurs [12]. With the TRA method, a risk assessment is carried out, with the help of which the level of risk is determined in terms of the probability of occurrence (likelihood) and the severity that can be caused [9]. Risk assessment is carried out in order to properly analyze and evaluate the possible risks and impacts [13]. A risk analysis is then carried out from the risk assessment, whereby the risk analysis is a systematic process for calculating the level of the existing risk. The expected result of the risk analysis is a hazard classification. This highlights hazards that should be considered as priorities for emergency management programs [14].

Managing the risk of occupational accidents requires real breakthroughs that can not only measure the risk but also mitigate in detail all causal factors and impacts resulting from an accident risk [15]. A method capable of solving risks in a structured manner, from assessment to mitigation of cause and effect factors with multiple controls, is the Bowtie analysis method. Bow-tie analysis or BTA is a technique that refers to a butterfly-shaped chart that represents events. the risks one faces, simply put. However, the bow-tie methodology is an adaptation of three traditional safety system techniques: fault tree analysis, causal factor diagram, and event tree analysis [16]. This bowtie analysis graphically represents the relationship between hazards, initial events and possible consequences, thereby supporting the process of identifying the main causes and consequences associated with risks, as well as identifying the control steps necessary to avoid or reduce risks [17]. The advantage of the bowtie analysis method is that it allows researchers to distinguish between controls that reduce the probability of a spike event occurring and controls that reduce the magnitude of the consequences, which can reduce the magnitude of the expected consequences. In addition, bowtie analysis can also be used for all types of risks.

In bowtie analysis, recovery measures are required to reduce potential impacts when exposure control measures fail and to prevent potential increases in health risks [18]. Restorative actions are carried out by implementing remedial actions to reduce the impact of the consequences listed on the right side of the diagram. This research was carried out with the aim of providing information and assisting HSE officers with PT. Varia Usaha Beton (BSP Purwokerto) in identifying dangerous risks that may arise and assessing risks in the production process of precast concrete using the Task Risk Assessment method and knowing the causes and effects of potential hazards, as well as providing recommendations for improvements and control systems the bow-tie analysis method to minimize occupational accidents that occur.

2. Research Method

This research was conducted at PT. Varia Usaha Beton (BSP Purwokerto) in the HSE department. The subject of this study is the dangers that exist in the production process of ready-mixed concrete. The variables in this research are hazard identification (task phase, failure mode, consequence analysis, recovery analysis), risk assessment and risk control. Risk detection techniques include brainstorming, surveys, and distributing questionnaires [19]. The data sources used in this research are primary data and secondary data. Primary data was collected through observation and interviews. Observations were carried out directly in the production process in the area of the mixing plant, during the material filling process and during the production of concrete samples. Interviews were conducted with several related parties, in particular the head of the Health Safety and Environment (HSE) team and workers in the mixing plant area. Interviews were conducted with the HSE team leader to obtain an assessment of the extent and severity of the potential hazard. Secondary data was obtained from company data, including company profiles, standard operating procedures (SOP) and HIRARC data in 2022. This research phase begins with determining the research objectives, namely identifying dangerous risks, risk assessment and risk control in the ready-mix concrete manufacturing process to prevent industrial accidents occurring minimize. The steps in preparing a task risk assessment are, first, determining the type of work to be analyzed, second, identifying materials, equipment or work procedures, third, analyzing the potential hazards in each work activity, fourth, determining the level of risk for each work activity and finally the necessary ones Define protective measures [20]. The following evaluation criteria are used in this research:

Table 1 Degree of Probability [21]

Levels	Description	Information
5	Very likely/almost certain	Can occur with any disease/is the most common
4	Probably	Probably happens often
3	Moderate	Can happen multiple times
2	not how	The possibility of this happening is rare
1	Rarely	Can only occur under exceptional conditions

Table 2 Severity (Severity Level) [21]

Levels	Description	Information
5	Catastrophic	Deadly, more than one person. Toxic release with widespread impact, very large financial losses and long-term impact on cessation of all activities
4	Significant	Serious injury to several people, major losses and interruption of production
3	Moderate	Moderate injury. Requires medical attention
2	Irrelevant	Requires first aid/minor injury, moderate financial loss
1	Insignificant	There were no injuries and there were minor financial losses

Table 3 Risk Matrix [21]

Scale		Consequences (Severity)				
		1	2	3	4	5
Probability	5	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5

Risk control is based on a hierarchy of controls, namely elimination, substitution, technical, management and PPE. Then, from the identified risk categories, the dominant risk variable is extracted from the risk identification and assessment results and then an analysis is carried out using the bowtie method to identify the causes, effects and controls for each risk that arises.

3. Results and Discussion

3.1. Risk Assessment Task

Task Risk Assessment (TRA) is a hazard identification method carried out to find out what and how great are the potential hazards encountered during activities in order to prevent occupational accidents and control these hazards. Based on the risk identification and risk assessment performed, activity steps are determined to have a low to extreme level of risk. The job variables are then grouped according to risk level and then risk control is carried out. Risk control is based on a hierarchy of controls, namely elimination, substitution, technical, management and PPE.

Table 4 Material Preparation Risk Assessment Task

Project/task name :		**Ready-mixed concrete production**	**Workspace :**			**warehouse**
Project/task description :		**Material preparation**				
Reference number	**Specific task/activity steps**	**Identify potential hazards**	**S**	**L**	**R**	**Risk control**
1	Loading materials	Accidents in the factory area	3	2	6	Administration: There are traffic controllers (cleaning staff/warehouse staff) when trucks maneuver for loading and unloading.
		Slipped due to slippery storage area	2	3	6	PPE: Use of safety shoes and helmet
2	Material Unloading	Exposed to fly ash dust	3	4	12	Administration: The operator ensures that the hose connections are installed correctly.
		Air pollution from clogged hoses	2	3	6	Administration: Regular inspection and maintenance of hoses.
		Exposure to addictive substances	3	2	6	PPE: Use of gloves and masks.
3	Fill material into the cold container	Hit backwards by a wheel loader	3	3	9	Administration: There is a dedicated lane for the use of wheel loaders.
4	Refueling the wheel loader	Fire caused by spilled diesel fuel while refueling	4	3	12	Administration: There is a container for storing spilled diesel fuel.

Table 5 Risk Assessment Concrete Production Process

Project/task name :		**Ready-mixed concrete production**	**Workspace :**			**Batching Plant**
Project/task description :		**Concrete production process**				
Reference number	**Specific task/activity steps**	**Identify potential hazards**	**S**	**L**	**R**	**Risk control**
1	Load sand and stones into the mixing tub	Falling material falling while the conveyor belt is running	2	4	8	PPE: Wear a safety helmet
2	Conveyor belt operation	Material impairment due to defective conveyor belt	3	2	6	Administration: Check the conveyor belt regularly.
		Jammed conveyor	3	2	6	Administration: Do not touch the conveyor belt when the conveyor belt is in operation.
3	Using a dust collector	Air pollution from clogged dust collectors	3	4	12	Administration: Understanding the application of WI dust collector cleaning.
4	Activities in the control room	Fell due to the slippery stairs in the control room	2	3	6	PPE: Use of safety shoes and helmet.
		Electric shock due to an electrical short circuit	4	2	8	Substitution: Replacing a damaged cable with a new cable.
5	Use of hoses	An oil leak occurred due to a broken hose	3	2	6	Administration: Regular maintenance and inspection of hoses.
6	Loading truck mixer	Slipped due to slippery production area	2	3	6	PPE: Use of safety shoes and helmet.
		Was hit/knocked by a mixer truck that was about to load	3	2	6	Administration: When loading the truck mixer, there is an helper or a kernet.
		Decrease in production materials	2	4	8	PPE: Use of a helmet.
7	Work in the production area	Breathing problems due to dusty production areas	2	4	8	PPE: Use of masks.
		Noise	3	4	12	Technology: The vibrator area is covered.
8	Use of generator sets	Finger hit by generator fan	3	3	9	Administration: Do not touch the generator fan while it is operating.
		Electrical short circuit	4	3	12	Substitution: Replacing damaged cables with new cables.
		The roof of the generator house collapsed	2	3	6	Replacement: Replacement of the generator roof.
9	Air compressor operation	Noise	2	3	6	PPE: Use of earmuffs/earplugs
		Slipped due to oil leakage due to air compressor motor leak	3	3	9	Administration: There is an oil storage container

Table 6 Risk Assessment Task Production of Concrete Samples

Project/task name	: ready-mixed concrete production	**Workspace**	: Quality assurance laboratory			
Project/task description	:Sample preparation					
Reference number	**Specific task/activity steps**	**Identify potential hazards**	**S**	**L**	**R**	**Risk control**
1	Concrete mix	Inhaling fly ash and cement dust while mixing concrete	2	4	8	PPE: Use of masks
		Exposure to addictive substances	3	2	6	PPE: Use of gloves and masks
		Influenced by the rotation of the mixer motor	3	2	6	Administration: Do not touch the concrete mixer while it is in operation
2	Pour concrete into forms	Affected by spilled concrete mix	1	4	4	PPE: Use of gloves and safety shoes
3	Drying of concrete samples	When the sample was lifted, the concrete sample was crushed	2	3	6	PPE: Use of safety shoes and helmet
4	Sample soaking	There is a puddle of water	3	3	9	Administration: Change the soaking water of the sample regularly
5	Compressive strength test	Exposed to the explosion of the test object	3	2	6	Engineering: Installation of screens on pressure testing machines
		Hit by test subject	2	3	6	PPE: Use of gloves and safety shoes
6	Pattern cleaning of the mold	Tools fall when cleaning the mold	2	3	6	PPE: Use of gloves and safety shoes
		Wedged in the pattern shape	2	3	6	PPE: Use of gloves

3.2. Bowtie Analysis

After identifying the dominant risk variable from the results of risk identification and assessment, the bowtie method is then used to identify the causes, effects and controls for each risk that arises. From the task risk assessment method, the two variables with the highest risk were taken with a risk value of 12, namely the risk of exposure to fly ash dust and the risk of electric shock.

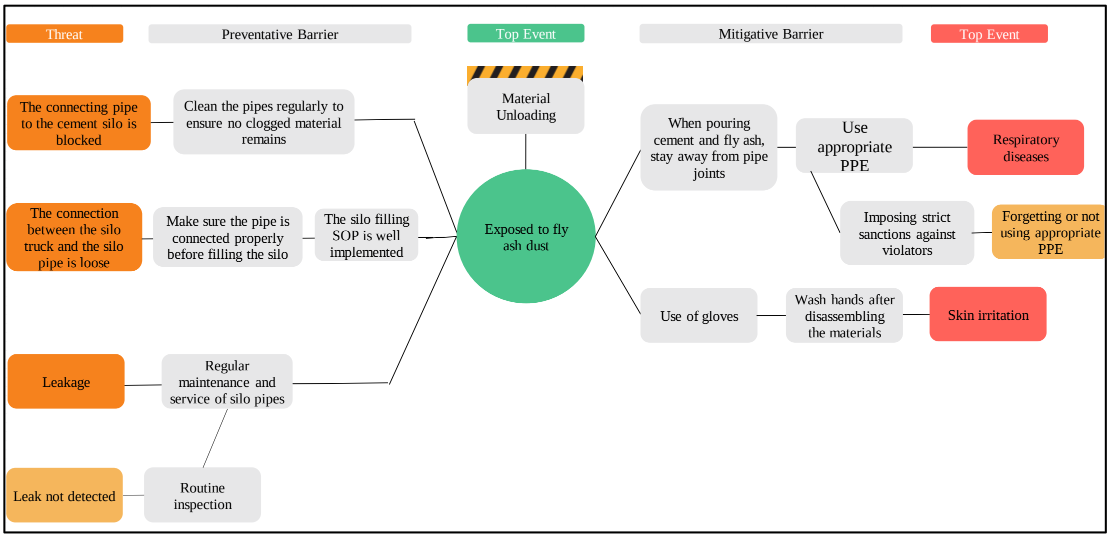

Figure 1 Bowtie Analysis Risk of Exposure to Fly Ash Dust

From Figure 1, it is clear that the main event in the material unloading process is the risk of exposure to fly ash and cement dust. There are three treatments at this top event: The connecting pipe to the cement silo is blocked with a preventive barrier, namely cleaning the silo pipe regularly. The second treatment then provides a preventive barrier to the connection between the truck bulk and loose silo pipes by first ensuring that the connecting pipe is correctly installed before the material is poured into the cement silo. In addition, the filling of the material into the cement silo must also be carried out in accordance with the applicable SOP. When dealing with pipe leaks, there is a preventative barrier, namely regular maintenance and upkeep to prevent leaks. There is then escalation control on this barrier, namely through routine inspections of the escalation factors through undetected leaks. Then the presence of this treatment causes a consequence, namely breathing problems, by mitigating the barrier, namely through distancing when disconnecting pipe connections and using appropriate PPE such as masks. Then an escalation factor arises from this barrier, namely intentional or forgotten actions of workers using PPE with possible escalation control, in particular by imposing strict sanctions on workers who do not use PPE. The second consequence of skin irritation is the weakening of the barrier, namely wearing gloves when breaking down the material and washing hands after breaking down the material.

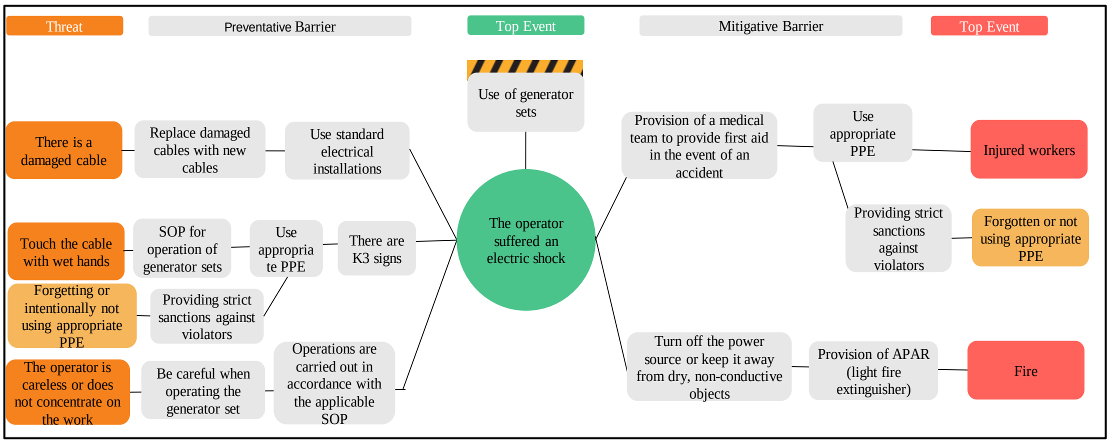

Figure 2 Bowtie Analysis Risk of Electric Shock

From Figure 2, it is clear that the biggest event when using a generator is the risk of electric shock. There are 3 treatments at this top event, namely treating damaged cables with a preventive barrier, namely by replacing damaged cables with new cables and using standard electrical installations. Then the second treat is touching the cable with wet hands with a preventative barrier, namely the implementation of SOPs for the use of machines, there are K3 signs for the flow of electricity and the use of PPE, where in this barrier there are escalation factors for this Operators who forget or intentionally fail to use PPE can be addressed as part of escalation control by imposing strict sanctions on workers violating the use of PPE. Then thirdly, if the operator is careless or not concentrating on performing his work, take a preventive measure: The operator shall exercise caution when operating the generator motor and operate it in accordance with the applicable SOP. Consequences arise from this treatment, namely that injured workers receive compensation, namely through the provision of first aid as first aid in the event of an injury and through the use of appropriate PPE when there is an escalating factor that leads to failure to mitigate the damage, viz due to workers' negligence. However, the escalation factor can be overcome through escalation controls, especially strict sanctions for workers who violate the use of PPE. The consequences of injured workers are mitigated through the provision of first aid as a first aid measure in the event of an injury and through the use of appropriate PPE during electrical work on generator motors when an escalation factor is present that results in failure leads to damage reduction namely due to the negligence of the workers while using it. While there is adequate PPE, this escalation factor can be overcome through escalation control, particularly strict sanctions for workers violating the use of PPE. Then there is a remedy for the consequences of a fire by turning off the power source and moving the power source away from non-conductive objects. If an electrical short circuit occurs, use APAR in the event of a fire.

4. Conclusions

This research provides conclusions on hazardous risk identification, risk assessment and risk control in the precast concrete manufacturing process using the task risk assessment method combined with the bowtie analysis method to determine the causes, effects and controls that can be carried out. From work activities where potential hazards have been identified and risk assessments of the hazards by multiplying the severity value and the probability value. The risk assessment results are then classified into several risk level categories, namely low, medium, high and extreme risk levels. It was found that there were up to 1 risk with a low risk category, 27 risks with a medium risk category and 11 risks with a high-risk category. The risk assessment identified the high risk of operating the generator set, which poses a risk of electric shock. From the risk level “High” onwards, a cause analysis and control were carried out using the bowtie analysis method. The cause of this risk is that a cable is damaged. The control can be carried out by replacing the damaged cable with a new cable and using electrical installations that comply with standards. The second cause is touching the damaged cable through controlled use of a generator motor using appropriate PPE. appropriate and there are K3 signs. The escalation factor is forgetting or not using appropriate PPE and escalation control imposes strict sanctions on violators. SOP. This risk results in workers being injured, which can be remedied, in particular by providing a medical team and using appropriate PPE. The escalation factor is that there are workers who forget or intentionally fail to use PPE, and escalation control imposes strict sanctions on workers who violate this. The second effect is the occurrence of fires, which can be contained by turning off the power source and moving it away from dry, non-conductive objects and using APAR if a fire occurs.

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