



**OPTIMIZATION OF ENVIRONMENTAL, OCCUPATIONAL SAFETY AND HEALTH MANAGEMENT THROUGH AUTOMATIC WATERFILL INNOVATION FOR FUEL EFFICIENCY, TIME EFFECTIVENESS, AND MINIMIZING POTENTIAL FOR HAZARDOUS AND TOXIC WASTE CONTAMINATION IN COAL MINING**

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**ABSTRACT**

The purpose of this study is to implement automatic waterfill innovation for fuel efficiency, time effectiveness, and minimizing the potential for hazardous and toxic waste contamination in coal mining. This research method is quantitative with a research and development approach. This research was conducted at PT. Antareja Mahada Makmur site Multi Harapan Utama. The research was conducted in June 2024. This research began with an analysis of the current conditions regarding the water truck process in the waterfill; setting targets with Specific, Measurable, Achievable, Relevant, and Time-Bound indicators. After the implementation of automatic waterfill, the operational time required to turn the waterfill on and off was drastically reduced because automation eliminates manual steps. It also significantly reduced the total waterfill running time per shift from 480 minutes to just 144 minutes, which means significant energy savings, increased time efficiency, and reduced fuel waste and potential damage due to excessive operations. The application of automatic waterfill in coal mines brings many benefits, including improved operational quality, cost savings, increased safety, and reduced environmental impact. In addition, this system also has a positive impact on operator motivation and job satisfaction.

Keywords: automatic waterfill; coal mining; fuel efficiency

**How to cite (in APA style)**

Amirudin, A., Zulkarnaen, Z., Gunawan, G., Saptaputra, S. K., & Lestari, I. A. I. D. (2024). Optimization of Environmental, Occupational Safety and Health Management through Automatic Waterfill Innovation for Fuel Efficiency, Time Effectiveness, and Minimizing Potential for Hazardous and Toxic Waste Contamination in Coal Mining. *Indonesian Journal of Global Health Research*, 6(S5), 771-786. <https://doi.org/10.37287/ijghr.v6iS5.4650>.

**INTRODUCTION**

Occupational safety and health (K3) is a top priority in the coal mining industry, given the high risk of accidents and environmental impacts inherent in mining operations (Matloob et al., 2024). One of the modern approaches to improving safety in mining is through the implementation of the SMART Safety program. SMART Safety is a concept that integrates advanced technology with data-driven safety practices to minimize risk, improve monitoring,

and encourage better decision-making in terms of occupational safety. SMART in this context refers to Specific, Measurable, Achievable, Relevant, and Time-bound, which means the program is designed with clear objectives, measured against specific safety indicators, relevant to the needs of the mine operation, and has a specific time target to achieve the results (Zhang, 2024).

The implementation of SMART Safety in coal mines involves various digital technologies such as IoT (Internet of Things) sensors, real-time monitoring systems, big data analytics, and technology-based personal protective equipment (PPE). IoT sensors, for example, can be installed at various critical points to detect potential hazards such as toxic gases, ground movement, or fire. Real-time monitoring systems allow mine managers to continuously monitor environmental conditions and equipment performance, so that problems can be identified and addressed before they cause accidents (Vishwakarma, 2024).

The SMART Safety approach also emphasizes the importance of workforce involvement in creating a safe working environment. With clear and measurable indicators, workers can better understand the safety standards that must be met. Data-driven systems also enable the identification of unsafe behavior in the workplace and provide workers with immediate feedback, either through wearable devices or digital notifications. This encourages faster and more accurate decision-making and builds a stronger safety culture at the mine (Fang et al., 2024) (Hwa & Seok, 2020). The success of the SMART Safety program implementation has been proven in various industrial sectors, including mining. By using data and predictive analytics, mining companies can identify accident trends or potential risks before an incident occurs. This not only helps reduce the number of accidents, but also increases operational efficiency, as downtime caused by accidents can be minimized (Kemajl et al., 2024).

The work process in mining has high potential for danger and risk, therefore aspects of safety, occupational health, and the environment are requirements that must be met in every work activity (Agus Amirudin et al., 2023). In coal mining, where harsh working conditions and hazardous environments are part of daily operations, the SMART Safety program can play an important role in protecting workers and reducing operational risks. The implementation of this program is in line with international occupational safety regulations, including standards set by the International Labour Organization (ILO) and other organizations that focus on safety in the extractive industry environment (Dadsena et al., 2024).

Coal mining operations often face significant challenges related to efficiency and safety, especially in dust management and water truck (WT) charging. In areas such as the GTR pit, West pit, and hauling roads, the frequent dusty road conditions are a major challenge. Thick dust can reduce visibility, increase the risk of accidents, and pose health problems for workers. The use of water trucks for dust control is essential in mining operations to ensure safety and efficiency. Dust generated in mining activities poses significant health risks and can lead to operational hazards such as coal dust explosions. Effective dust control mechanisms, including the use of water trucks, are essential to reduce these risks. Water trucks are particularly useful in open pit mines where they can be optimized for efficient dust suppression through routing strategies, minimizing travel distances and maximizing coverage (Khajouei et al., 2020).

However, in practice, the process of filling water on water trucks is currently still done manually, where operators must get on and off the unit to turn the waterfill system on and off. This causes operational delays, and in some cases, operators are forced to leave the waterfill

on even though it is not in use, which not only results in wasted fuel but also has the potential to damage equipment and extend maintenance time. In addition, damage or disruption to the waterfill system often occurs, extending the time required for water filling and reducing mine productivity. (Ramadhan & Nurhadi, 2023).

The use of an automated waterfill system offers a solution that can overcome this problem. With automation, operators no longer need to be manually involved in the water filling process, which not only saves time but also improves work safety. This system can also reduce fuel consumption by eliminating the need to leave the waterfill running when not in use (Jamás et al, 2023). In addition, automation can help reduce the potential for hazardous and toxic waste contamination, which is a major problem in mining areas, by regulating water flow more precisely (Xie et al., 2024). This technological innovation is in line with global efforts to improve operational efficiency and environmental sustainability in the mining sector. Implementing automation systems like this allows mining companies to comply with stricter safety standards while maximizing productivity (Zvarivadza et al., 2024). The purpose of this study is to implement automatic waterfill innovation for fuel efficiency, time effectiveness, and minimizing the potential for hazardous and toxic waste contamination in coal mining.

## **METHOD**

This research method is quantitative with a research and development approach. This research was conducted at PT. Antareja Mahada Makmur Kutai Kartanegara. The research was conducted in June 2024. This research began with an analysis of the current conditions regarding the water truck process in the waterfill; setting targets with Specific, Measurable, Achievable, Relevant, and Time-Bound indicators. After that, it was continued successively with the 4M-1E analysis; 5 Why Analysis; 5W-2H Analysis; Implementation of Improvements; and Evaluation of Results on Quality Cost, Delivery, Safety, Environment, and Morale. Primary data were gathered through direct observations, interviews with relevant personnel, and analysis of company records related to the process. Observations focused on documenting each step within the waterfill process, noting inefficiencies or safety concerns. Interviews were conducted with operators, supervisors, and managers to gain insights into current challenges and improvement needs. Additionally, secondary data were obtained from existing internal reports and documents, which were used to supplement the primary data.

## **RESULT**

### **Root Cause Analysis of the Problem**

#### **Analysis 4M-1E**

4M-1E analysis is an analysis method used to identify and solve problems in a work process by looking at the five main factors that affect performance, namely Man, Machine, Material, Method, and Environment. 4M-1E analysis can be seen in Table 1.

Table 1 shows that almost all aspects of waterfill operations are in a suboptimal condition (“Bad”), except for sufficient water availability. This condition emphasizes the urgent need to adopt more reliable automation and equipment technologies, which will increase efficiency, reduce environmental risks, and lower fuel consumption and pollution in the mine. In the “Man” aspect, operators have to operate the waterfill manually, causing time inefficiencies and potential hazards, while the system should allow for remote control and automation. In the “Machine” aspect, the waterfill often experiences disruptions, causing high fuel consumption and air and noise pollution, which could have been minimized with more reliable equipment. Water distribution is also disrupted, although water availability remains

sufficient, indicating a problem with the equipment, not the water resource. The manual process of filling the water truck extends operational time, which could have been optimized with automation. In terms of the environment, waterfill repairs are at high risk of oil and diesel contamination, indicating the need for better environmental management measures. Overall, these conditions indicate an urgent need to improve efficiency with automation technology and better management.

Table 1.  
4M-1E Analysis

Aspect	Current (WAH)	Should be (WSBH)	Result
Man	The operator must climb up and down the unit to operate the waterfill manually.	Operators can operate the waterfill from within the unit using a remote system.	Bad
	Sometimes leaving the waterfill running even when not in use.	Waterfill automatically turns off when not in use.	Bad
Machine	Waterfill often experiences breakdown/trouble.	Waterfill functions well and has reliability in operation	Bad
	High fuel consumption	Low fuel consumption	Bad
	Air and noise pollution occurs	No air and noise pollution occurs	Bad
Material	Water distribution is disrupted due to problems with the waterfill.	Fast and efficient water distribution with well-functioning equipment.	Bad
	Sufficient water availability.	Availability of sufficient water and maintaining its quality.	Good
Method	The water truck filling process takes a long time due to manual operation.	Automatic water truck filling process to reduce filling time.	Bad
Environment	During the repair process, the potential for oil and diesel contamination to the environment is high.	During the repair process the potential for contamination is low.	Bad

### 5 Why Analysis

5 Why Analysis is a simple yet effective technique for finding the root cause of a problem by asking “why” five or more times until the root cause of the problem is found. This method aims to avoid solving problems that only address symptoms, and focus more on the underlying causes. 5 Why Analysis can be seen in Table 2.

Tabel 2.

Analisis 5 Why

Aspect	Problem	Why (1)	Why (2)	Why (3)	Why (4)	Why (5)
Man	The operator must climb up and down the unit to operate the waterfill manually.	Waterfill operation is still manual and requires the engine to be started directly.	The waterfill engine still cannot be operated remotely			
	Sometimes leaving the waterfill running even though it is not being used.	It takes longer to turn off the waterfill	The process of turning off the waterfill is still manual	Waterfill has not installed automatic shutdown sensor for object detection		
Machine	Waterfill often experiences breakdown/trouble.	When operating, the water pump experiences high vibrations.	Still using conventional diesel engines	Have not found a replacement power source for other waterfill drivers		

Aspect	Problem	Why (1)	Why (2)	Why (3)	Why (4)	Why (5)
	High fuel consumption.	Running hours engine water fill is high	Waterfill has not been used as needed			
	Air and noise pollution occurs.	Waterfill still uses conventional diesel engine power	Have not found a replacement power source for other waterfill drivers			
Material	Water distribution is disrupted due to problems with the waterfill.	Waterfill often experiences breakdown/trouble.	When operating, the water pump experiences high vibrations.	Still using conventional diesel engines	Have not found a replacement power source for other waterfill drivers	
Method	The water truck filling process takes a long time due to manual operation.	The waterfill engine still cannot be operated remotely				
Environment	During the repair process, the potential for oil and diesel contamination to the environment is high.	Diesel engines require regular maintenance of oil and filter changes at the waterfill location.	Waterfill still uses conventional diesel engine power	Have not found a replacement power source for other waterfill drivers		

Table 2 reveals the problems that mostly stem from the use of old and manual technology in waterfill operations. Without automation and more efficient energy use, problems such as long operating times, machine breakdowns, pollution, and environmental risks will continue to occur. Proposed solutions include the application of automation technology, remote control, and the search for more environmentally friendly energy alternatives to improve efficiency and reduce negative impacts on the environment and operations.

### Prepare a repair plan

#### 5W-2H Analysis

This analysis uses seven basic questions consisting of 5W (What, Why, When, Where, Who) and 2H (How, How much) to ensure that all aspects of the problem or plan have been considered properly. 5W-2H Analysis. 5W-2H Analysis can be seen in table 3.

Table 3 illustrates the action plan to address several issues in the waterfill system at the mine. The main problem identified is the absence of a replacement power source for the waterfill drive other than a conventional diesel engine. The solution is to replace the diesel engine with an electric induction motor to make operations easier, more energy efficient, and more environmentally friendly, which will be carried out by the Auxiliary (Aux) team at the waterfill location in the first week of March 2024 at a cost of IDR 14.750.000. Another problem is the absence of an automatic shutdown sensor to detect the presence of a water truck (WT). To overcome this, a proximity sensor will be installed at the WT filling position,

at a cost of IDR 420.000, also carried out by the Aux team in the first week of March 2024. In addition, the waterfill machine currently cannot be operated remotely, so an integration will be carried out between the induction motor and proximity sensor to enable remote operation, at an estimated cost of IDR 525.000 in the second week of March 2024.

Table 3.  
5W-2H Analysis

What (The main cause)	Why (Reasons and Purposes)	How (Action)	Who	Where	When	How Much (Cost)
Have not found a replacement power source for other waterfill drivers	Looking for a replacement for other driving forces to operate the waterfill, to support easier, energy-efficient and environmentally friendly waterfill operations.	Replacing conventional diesel engines with induction motors (electric power)	Team Aux	Waterfill	W1 Maret 2024	IDR14.750.000
Waterfill has not installed automatic shutdown sensor for object detection Waterfill belum digunakan sesuai kebutuhan	So that the water fill can operate effectively and efficiently, and only operate when there is a WT filling it.	Installing a proximity sensor at the WT position point for charging	Team Aux	Waterfill	W1 Maret 2024	IDR 420.000
The waterfill engine still cannot be operated remotely	To simplify the process of turning the waterfill on and off.	Assembling and combining proximity sensors with induction motors (electric power)	Team Aux	Waterfill	W2 Maret 2024	IDR 525.000

## Implementation of Improvements

### Application of Electric Motors and Sensor Objects

Table 4 identifies the main causes of problems in the waterfill system and the solutions implemented to fix them. Initially, the waterfill used a conventional diesel engine that often failed, produced air and noise pollution, and was at risk of polluting the environment. The solution was to replace the diesel engine with an electric induction motor, which made the waterfill more reliable, non-polluting, and did not require fuel. In addition, previously the waterfill did not have an automatic shutdown sensor, which resulted in the system often running continuously. After the installation of the proximity sensor, the waterfill can automatically turn on and off according to the presence of the water truck (WT), which improves energy efficiency. Before this change, the waterfill was running continuously, but now it only operates as needed, improving energy efficiency. To overcome the manual operation of the waterfill, remote operation is applied by combining induction motors and proximity sensors. This allows the waterfill to be turned on and off automatically, so that operators do not need to get on and off the unit to operate it. Filling becomes faster without

delay, and the risk of operator accidents due to slipping or falling in the waterfill area is reduced.

Table 4.  
Application of Electric Motor and Object Senso

Root Cause	Solution	Condition Before	Condition After	Results / Impact
Have not found a replacement power source for other waterfill drivers	Replacing conventional diesel engines with induction motors (electric power)	Using a conventional diesel engine	Using induction motor (electric power)	Waterfill rarely experiences breakdown/trouble No air pollution and noise pollution No potential for oil and diesel contamination Does not use fuel
Waterfill has not installed automatic shutdown sensor for object detection	Installing a proximity sensor at the WT position point for charging	No sensors	Proximity sensor installed near the waterfill	Waterfill can automatically turn on when there is a unit / WT in the filling area, and turn off when the WT leaves the waterfill.
Waterfill belum digunakan sesuai kebutuhan		Waterfill keeps running	Waterfill running as needed	High energy efficiency (works as needed)
The waterfill engine still cannot be operated remotely	Assembling and combining proximity sensors with induction motors (electric power)	Manually start and stop the engine	Waterfill can turn on and off automatically	Operator does not need to get on/off the unit to operate the waterfill. Filling the waterfill is fast without any delay in the process of turning on the waterfill The potential for operator accidents due to falling/slipping in the waterfill area is small.

### Wiring Diagrams

This wiring diagram illustrates an automatic waterfill control system using a proximity sensor that detects the presence of a water truck and controls the electric motor to start or stop filling water automatically. This system is supported by a relay that acts as an automatic switch to control the flow of power to the motor or actuator based on signals from the sensor, and a power supply that converts AC power to DC power required by the sensor and relay. The main purpose of this system is to improve fuel efficiency, time effectiveness, and reduce the potential for hazardous and toxic waste contamination. The wiring diagram can be seen in Figure 1.

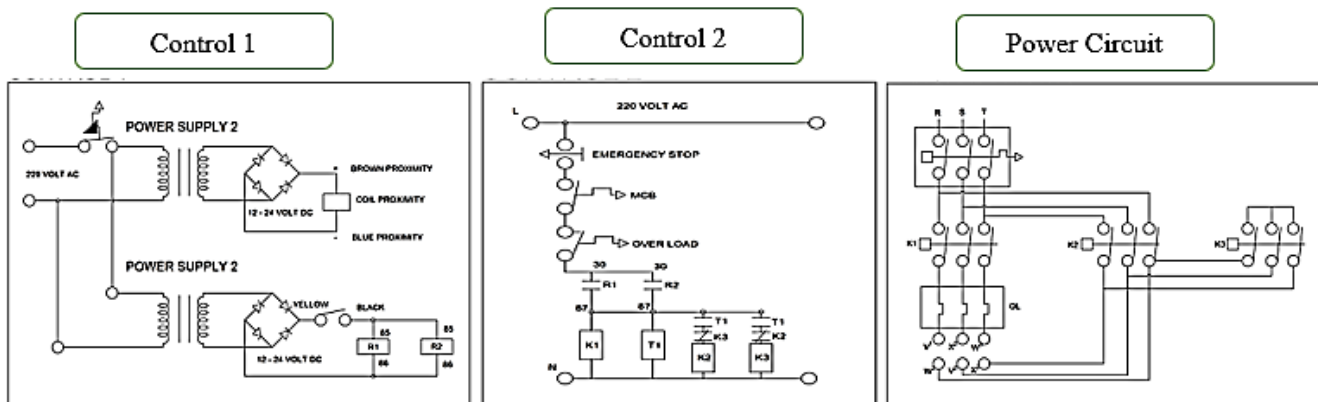


Figure 1. Wiring Diagram

Wiring diagram of control 1 scheme for an automatic waterfill system that uses an electric motor and proximity sensor to detect objects. This diagram shows how the sensor components and power supply are connected to operate the waterfill system automatically. Control 2 wiring image is a control system for automatic waterfill that uses an electric motor with protection against overload conditions and an emergency stop feature. The power circuit diagram is a power circuit to operate an electric motor in an automatic waterfill system. This diagram shows how the electric current from the power source is connected through various components such as contactors, relays, and overload protection to drive the electric motor..

**Control 1**

The wiring diagram shown in Figure 1 is an automated control system for a waterfill that uses an electric motor and proximity sensors to detect objects, in this case most likely a water truck (WT). The system uses two power supplies that convert 220 Volt AC to 12-24 Volt DC via a transformer and rectifier (bridge rectifier), which is then used to power the proximity sensors and other control components. The proximity sensors in this system have three main connections: the brown and blue wires connect to the positive and negative power sources, while the proximity coil is used to detect the presence of the WT and trigger the system operation. When WT approaches the water filling area, the proximity sensor will detect its presence and send a signal to the relay (R1 and R2), which functions as an automatic switch. This relay is connected through pins 85 and 86, and when the sensor sends a signal, the relay will be activated to connect the power flow to the electric motor or actuator, thus starting the water filling process automatically. In this condition, the operator no longer needs to operate the waterfill manually, because the system will function automatically according to the sensor detection. In addition, the system is also designed to increase efficiency by automatically turning off the waterfill after the WT leaves the area, thus avoiding wasting energy or fuel. These relays and proximity sensors are carefully arranged to operate only when needed, which not only saves fuel and time, but also reduces the potential for hazardous and toxic waste contamination that can occur in manual operations. Overall, this diagram reflects the technological innovation designed for high efficiency in automated waterfill management in the mining environment.

**Control 2**

Control 2 wiring diagram shows an electric motor control system for automatic waterfill equipped with various safety features, such as emergency stop, overcurrent protection (MCB), and overload protection. Relays (R1 and R2) and contactors (K1, K2, K3) are used to automatically control the power flow to the motor based on signals from the control system. This system is designed to ensure efficiency and safety in waterfill operations, as well as

reduce the risk of motor damage and environmental contamination, in accordance with your research that focuses on fuel efficiency, time effectiveness, and minimizing the potential for hazardous and toxic waste contamination. The wiring diagram shown in the Control 2 figure is an electric motor control system for automatic waterfill, which is equipped with various safety features. This system works on 220 Volt AC as the main power source. One of the main safety features is Emergency Stop, which allows the operator to cut off the power in an emergency to prevent accidents or further damage. In addition, there is an MCB (Miniature Circuit Breaker) which functions to protect the system from short circuits or surges, ensuring the system remains safe from electrical interference.

This system is also equipped with overload protection, which will cut off the electric current if the motor is overloaded, thus preventing damage due to excessive heat. Relays (R1 and R2) are used to automatically activate or deactivate the motor, with signals from sensors or other controls. These relays work together with contactors (K1, K2, K3), which function as electrical switches to channel power to the motor. Terminals 30 and 87 are used to connect the relay to the contactor, thus allowing efficient control of the current to the motor. Overall, the system is designed to provide automatic control of electric motors in waterfill, with safeguards that ensure safe and efficient operation. Features such as emergency stop, overload protection, and relay control ensure fuel efficiency, time effectiveness, and minimization of potential hazardous and toxic waste contamination, which is in line with your research objectives on automated waterfill in the mining industry..

### ***Power Circuit***

The wiring diagram shown is a three-phase power circuit used to operate an electric motor in an automatic waterfill system. This circuit takes power from three phases (R, S, T) as the main power source. This three-phase system is chosen because it is more efficient and suitable for operating large-power motors, such as those used in waterfill applications. The contactors (K1, K2, K3) function as automatic switches that connect or disconnect the power supply to the motor based on signals from the control system. K1 functions to start the motor, while K2 and K3 may control various modes of motor operation, such as adjusting the direction of rotation or the motor load. In addition, this system is equipped with overload protection (OL), which will cut off the electric current if the motor works beyond its safe capacity, preventing damage due to overheating. Terminals U, V, W on the contactor are directly connected to the motor to supply power, while terminals X, Y, Z are used for additional control purposes, such as controlling the rotation or speed of the motor. Overall, this circuit is designed to automatically and efficiently provide power to the electric motor, ensuring that the waterfill operation runs smoothly and safely. Overload protection ensures that the motor is not overpowered, which will extend the life of the motor and reduce the risk of damage. This supports your research goals to improve fuel efficiency, time effectiveness, and minimize the potential for hazardous and toxic waste contamination in automated waterfill operations.

### ***Automatic Waterfill Condition***

Figure 2 shows an automated waterfill system that uses an electric motor and proximity sensors to optimize the operation of filling water into a water truck. The system is designed to improve fuel efficiency, as the waterfill only operates when the sensors detect a truck is ready to be filled. In addition, this automation also reduces the time required for filling and minimizes the potential for hazardous and toxic waste contamination, as manual interaction is minimized. An electrical control system located within the panel automatically regulates the entire operation, ensuring that the waterfill operates efficiently and safely.



Figure 2. Waterfill Condition

**Evaluation of the Results of the Application of Automatic Waterfill in Water Truck Filling**

Table 4.

**Evaluation of the Results of the Application of Automatic Waterfill in Water Truck Filling**

Process Flow	Should be (WSBH)	Duration (min)	Actual (WAH) - Before Improve	Duration (min)	Actual (WAH) - After Improvement	Duration (min)
WT enters waterfill	WT reposition with reverse parking	0,5	WT reposition with reverse parking	0,5	WT reposition with reverse parking	0,5
Turning on the waterfill	Walk to the water pump	5	Walk to the waterpump to turn on the waterpump (start of shift only)		Waterfill turns on automatically	
	Perform P2H and turn on the water pump	5				
Waiting for the waterfill filling process	Waiting for the charging process	9	Waiting for the charging process	9	Waiting for the charging process	9
Turn off waterfill	Walk to the water pump	5	Waterfill is left running until the end of the shift.		Waterfill turns off automatically	
	Turn off the water pump	0,25				
WT out of waterfill	WT leaves waterfill	0,5	WT leaves waterfill	0,5	WT leaves waterfill	0,5
Estimated time required/filling (minutes)	Only running during charging process	25,25	Keep running	9	Waterfill running only during filling	9
Estimated waterfill running/shift (minutes) (2 WT, 8x fills/WT)		193		480	The on and off process works automatically	144

Table 4. It is known that after the implementation of automatic waterfill, the operational time required to turn the waterfill on and off is drastically reduced because automation eliminates manual steps. It also significantly reduces the total waterfill running time per shift from 480 minutes to only 144 minutes, which means there are significant energy savings, increased time efficiency, and reduced fuel waste and potential damage due to excessive operations. This is in line with your research objectives to improve fuel efficiency, time effectiveness, and reduce the potential for hazardous and toxic waste contamination.

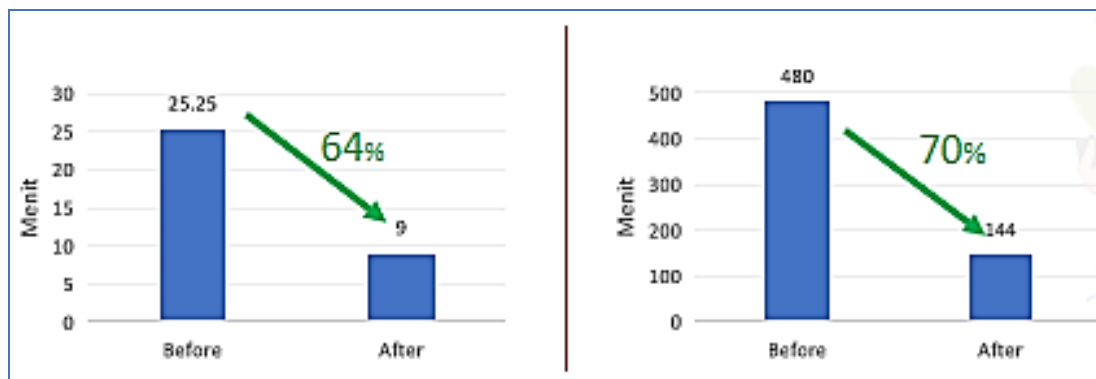


Figure 3. Application of Automatic Waterfill in Water Truck Filling

Figure 3 shows the evaluation of the implementation of automatic waterfill through a comparison between the conditions before and after the improvement in terms of the duration of filling the water truck (WT) and the duration of running waterfill per shift. Left Section (Water Truck Filling Duration - Before and After) shows Before automation, the water truck filling time was 25.25 minutes per cycle. This time includes the time to manually turn the waterfill on and off, in addition to the water filling time. After automation, the filling time was successfully reduced to 9 minutes per cycle, which is the ideal time for filling. This represents a 64% reduction in time, indicating a significant increase in the efficiency of water truck filling with the implementation of an automated system. Right Section (Waterfill Running Duration per Shift - Before and After) shows Before automation, the waterfill was left running until the end of the shift, with a total running duration of 480 minutes per shift, which resulted in wastage of energy and fuel. After automation, the waterfill running duration was drastically reduced to 144 minutes per shift, with a reduction in operational time of 70%. This is because the waterfill only runs when there is a water truck filling, and automatically turns off aft

**Potential Cost Benefit Per Year** Potential benefits are carried out on the Yanmar TS230R Unit Model with Fuel consumption of 168 gr/DK.Hour and Conversion to L/hour, namely 4.55 lite/hour

			<i>Estimated price of diesel per liter IDR.</i>
			<i>15.500</i>
Before improvement			
Time	Running duration (hours)	Diesel consumption (liters)	Cost
Per-shift	8	36,4	546.000
Per-Month	480	2184	32.760.000
Per-year	5760	26208	393.120.000
After improvement			
Cost RP. 0 (No operational costs)			
<i>Does not require solar, because it uses an electric energy source</i>			

			<i>estimated price of engine oil per liter IDR.</i>
			<i>21.000</i>
Before improvement			
Time	Replacement interval	Quantity	Cost
Per-Month	2	12	252.000
Per-Year	24	144	3.024.000
Source: Primary Data, 2024			
After improvement			
Fee RP. 0 (No service fee)			
<i>No oil changes, because it uses an electric energy source</i>			

**Improvement Costs**

IDR. 15.695.000

*Note: This improvement fee is charged once at the beginning.*

**Potential Benefit per Year**

(Cost Fuel + Cost Oil) - Improvement Cost

Rp380.179.000

Based on the analysis of potential benefits per year, it shows the potential benefits of implementing automatic waterfill based on electric motors, which replaces the previous system that used a diesel engine. Before the repair, the system used 36,4 liters of diesel per shift, with a total annual diesel consumption of 26.208 liters. The cost incurred for diesel reached IDR 393.120.000 per year. In addition, engine oil changes are carried out 12 times a year, with a total annual oil cost of IDR 3.024.000. With the implementation of automatic waterfill based on electric motors, there is no more diesel consumption or oil changes, because electric motors are more efficient and require less maintenance. The initial repair cost to replace the diesel system to an electric-based automatic system is IDR 15.695.000. After the repair, the annual operating cost for diesel and oil becomes IDR 0, meaning the total annual savings is IDR 396.144.000. After deducting the initial repair cost, the potential net savings per year reaches IDR 380.179.000. These savings demonstrate the extraordinary efficiency gained from the implementation of automatic waterfill, which not only reduces fuel and maintenance costs but also supports operational sustainability with fewer emissions and potential environmental contamination.

***QCDSEM Potential Benefits***

Aspect	Benefit
Quality	More consistent water distribution
	The possibility of waterfill damage is reduced
	Preventive maintenance made easier
	High tool efficiency (Not easily damaged)
Cost	Fuel savings (Potential fuel savings 26.208 liters or IDR. 393.120.000 per year)
	Reduced repair costs (Potential oil savings of 144 liters or IDR. 3.024.000 per year)
	Production operations are running optimally (Operations are not disrupted)
Delivery	Faster charging process
	Eliminates delays in the process of turning the waterfill on and off.
Safety	Reducing the risk of accidents in waterfill areas
Enviro	Reducing air and noise pollution
	Reduces potential contamination of oil and diesel due to repairs (Hazardous and toxic waste removed 144 liters of oil in 1 year)
Morale	Improving operator satisfaction and work motivation

The implementation of automatic waterfill in coal mining has provided significant benefits in terms of operations, costs, safety, and the environment. In terms of quality, water distribution is more consistent, reducing the risk of waterfill damage, and facilitating preventive maintenance. It also increases the efficiency of the equipment, making it more reliable and durable. In terms of costs, fuel savings reach 26.208 liters per year, with a potential savings of IDR. 393.120.000. In addition, reduced repair costs, such as oil savings of 144 liters per year (worth IDR. 3.024.000), further increase efficiency, with production operations not disrupted by repairs or delays. The water filling process also becomes faster and more efficient, with the elimination of delays caused by the need to manually turn the waterfill on and off. In terms of safety, the risk of accidents in the waterfill area is reduced, as automation eliminates manual operator interaction with the system. From an environmental perspective, the implementation of electric motors reduces air and noise pollution, as well as reducing the potential for oil and diesel contamination, with the elimination of 144 liters of oil waste per year, which is usually generated from diesel engine maintenance. Finally, the implementation of this automated system also increases operator motivation and job satisfaction, as they no longer have to perform tedious and potentially dangerous manual tasks, creating a safer and more comfortable working environment.

## **DISCUSSION**

The use of automatic waterfill in the mining industry has a significant positive impact, especially in terms of reducing direct interaction between humans and equipment. This is very important in efforts to improve work safety and minimize the risk of accidents and occupational diseases. The automatic waterfill system, supported by electric motor technology and object sensors, is designed to operate water filling on water trucks (WT) without manual intervention from the operator. Thus, the operator no longer needs to be involved in various operational steps that were previously carried out physically, such as turning on, turning off, or manually supervising the water filling process (Ramadhan & Nurhadi, 2023). In a manual system, operators often have to get on and off the unit to turn the waterfill on and off. This activity, although it seems simple, can increase the risk of work accidents, especially in harsh mining environments that do not always have ideal conditions. Risks such as slipping, falling, or getting entangled in equipment often occur in the waterfill area, which is usually full of pipes, pumps, and other equipment. With an automated system, operators no longer have to leave their vehicle cabins, because the waterfill will turn on and off automatically when the water truck approaches or leaves the filling area.

In addition, in the waterfill area which is exposed to water and other chemicals, such as oil and diesel, the potential for accidents is higher. The manual system forces operators to interact directly with equipment operating in this environment, which is often wet and slippery. (Araujo, 2023). With automated systems, exposure to these physical hazards can be minimized, as operations are performed remotely, and direct interaction with hazardous equipment is drastically reduced (Craig et al., 2024). In addition to reducing the risk of physical accidents, waterfill automation also helps reduce the potential for occupational diseases that arise from exposure to hazardous materials. In manual operations, operators are at risk of exposure to hazardous chemicals such as oil, diesel, and other fuels when they have to perform maintenance or refuel the waterfill. Repeated exposure to these chemicals can cause chronic diseases such as respiratory disorders, skin disorders, and nervous system diseases (Desai, 2024). The transition from diesel engines to electric motor-based water filling systems offers significant environmental and health benefits. Electric systems eliminate the need for diesel and oil, reducing operator exposure to hazardous chemicals and the risk of spills that can contaminate the environment. This shift is supported by advances in automation

technology, such as Arduino-based systems, which increase efficiency and safety in water management. (Pradana et al., 2024).

Reducing direct interaction with waterfill equipment also has a positive impact on the psychological condition and work motivation of operators. By reducing manual workload and potential exposure to hazardous working conditions, operators can work more calmly and focus on other safer tasks. This condition indirectly increases job satisfaction, reduces work stress, and increases overall productivity (Timotius, 2023). In addition, by using an automated system that works faster and more efficiently, operators do not have to wait long for the water filling process to complete. This reduces physical fatigue due to having to stand or monitor equipment for long periods of time. A more efficient process also eliminates operational downtime, which previously often occurred due to constraints in manual operation, such as damaged waterfills due to human error or being turned off too late after filling is complete (Dai, 2023). The use of automated waterfills also has a significant impact on environmental sustainability, which is directly related to long-term workplace safety. By reducing the use of diesel and oil, automation helps reduce air pollution and soil contamination from hazardous chemical spills. A cleaner and safer working environment indirectly contributes to the long-term health of workers, as they no longer have to work in a polluted environment. In the long term, the implementation of environmentally friendly automatic waterfill can also create a safer and more proactive work culture in maintaining work safety. Operators and management can focus more on preventative maintenance, managing a safe work environment, and improving more basic safety aspects rather than having to constantly deal with the risk of accidents or occupational diseases.

## **CONCLUSION**

Optimization of environmental management and occupational safety and health in coal mining is carried out through the implementation of automatic waterfill, the operational time required to turn the waterfill on and off is drastically reduced because automation eliminates manual steps. This also significantly reduces the total waterfill running time per shift from 480 minutes to only 144 minutes, which means there are significant energy savings, increased time efficiency, and reduced fuel waste and potential damage due to excessive operations. This is in line with your research objectives to improve fuel efficiency, time effectiveness, and reduce the potential for hazardous and toxic waste contamination. Therefore, by using automatic waterfill, the results obtained are: Low WT filling duration and low waterfill running duration. In addition, the use of automatic waterfill can reduce human interaction with tools, thereby minimizing the risk of work accidents and occupational diseases.

## **ACKNOWLEDGEMENTS**

The authors would like to express gratitude to the management and all employees of PT. Antareja Mahada Makmur, Multi Harapan Utama site, for their full support in the implementation of this research project.

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