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Downtime and Maintenance System Analysis of Reverse Osmosis (RO) Unit in a Beverage Manufacturing Company

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Abstract
This study aims to analyze downtime and maintenance systems in the Reverse Osmosis (RO) unit of a beverage manufacturing company. The research used a descriptive quantitative approach through direct observation, maintenance documentation, technician reports, and interviews with operators. The results showed that the RO unit experienced 31 hours of downtime during 720 hours of operation, with membrane fouling, clogged pre-treatment filters, high-pressure pump failure, and unstable water pressure identified as the main causes. The Mean Time To Repair (MTTR) was 2.58 hours, while the Mean Time Between Failures (MTBF) was 60 hours, with a machine availability rate of 95.69%. These findings indicate that although the RO unit is relatively reliable, the maintenance system still requires improvement, particularly in preventive maintenance scheduling and real-time monitoring. The implementation of PLC-based automation, PID control, and IoT-based monitoring is recommended to reduce downtime, improve operational efficiency, and maintain consistent water quality.

Keywords: Reverse Osmosis (RO), Downtime, Maintenance, Efficiency, Water Quality, Beverage Industry.

Introduction

In the beverage industry, water quality is a critical factor because water serves as the main raw material in the production process. The use of water that does not meet quality standards can affect product quality, consumer safety, and production consistency. Therefore, companies need reliable water treatment technology to ensure that the water used in production meets industrial standards. One of the commonly applied technologies is the Reverse Osmosis (RO) system, which functions to remove contaminants, ions, and dissolved substances through a special membrane. However, the effectiveness of this system depends not only on its filtration capability but also on the reliability of its operation and maintenance system.

Although the Reverse Osmosis (RO) system has an important role in maintaining water quality, in practice this system is inseparable from various technical problems. Interference with components such as clogged membranes, damaged high-pressure pumps, dirty filters, and interference with the control system can cause downtime or downtime in the engine. Downtime that occurs repeatedly can hinder the running of the production process, reduce efficiency, and increase the company's operational costs.

In the context of production efficiency, downtime is one of the important indicators that must be considered. The high level of downtime indicates that the production system is not running optimally. This not only impacts production delays, but can also affect a company's

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ability to meet market demand. Therefore, efforts are needed to identify the main causes of downtime and find the right solutions to improve the overall performance of the production system.

One approach that can be done is through the implementation of an effective maintenance system. A good maintenance system is not only corrective (repairing damage), but also includes preventive and predictive maintenance to prevent damage from happening before it occurs. Activities such as routine inspections, periodic component replacements, and monitoring of engine condition are important parts in maintaining the reliability of the Reverse Osmosis system. With the implementation of planned maintenance, companies can reduce the frequency of downtime, improve machine reliability, and extend the life of equipment.

In addition, the implementation of an optimal maintenance system also contributes to increasing the efficiency and stability of the production process in the beverage industry. An optimally operated machine will support production continuity and maintain consistent water quality. This is very important considering that competition in the beverage industry is getting tighter and requires companies to maintain quality as well as production efficiency.

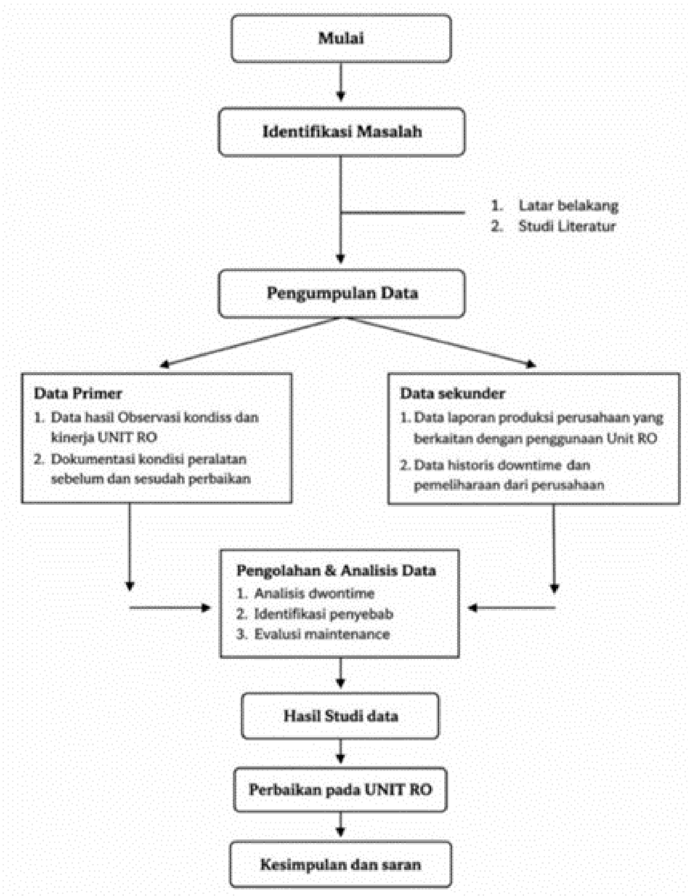

Figure 1. Flowchart

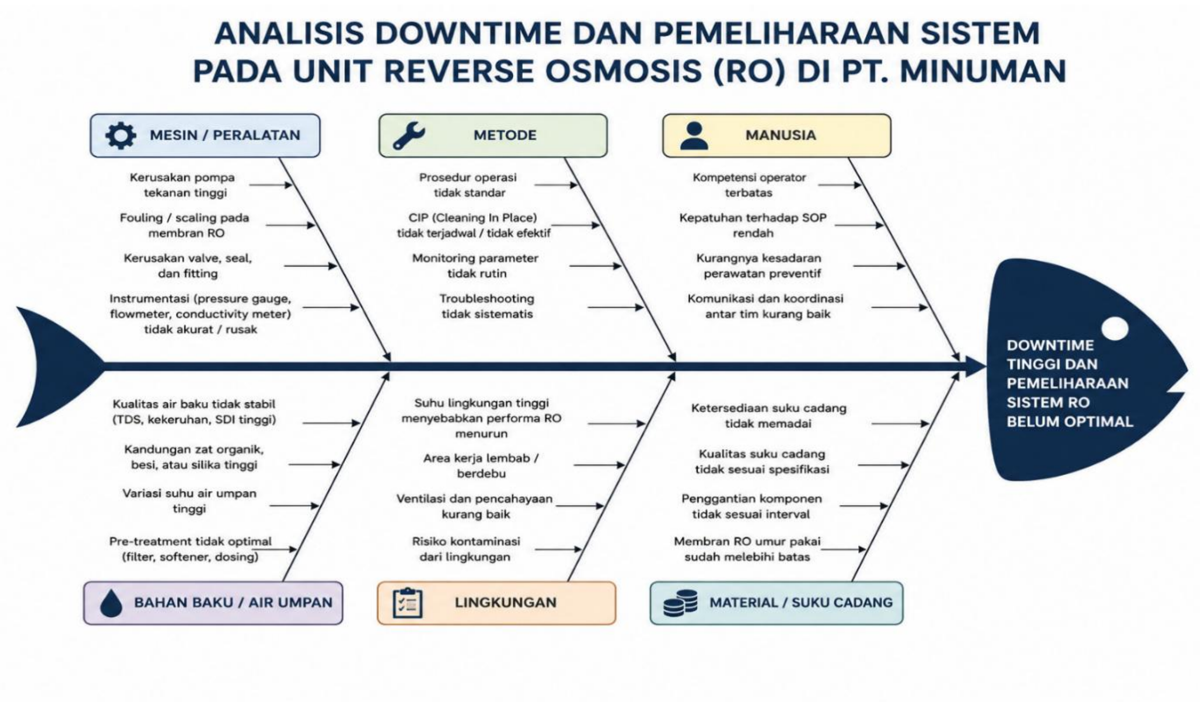

Figure 2. Fishbone Diagram

Automation on RO machines involves the use of intelligent systems to manage the water purification process with fewer direct operator interventions. This automation system is essential in the beverage industry because it can improve efficiency, maintain water quality, and reduce operator errors.

In addition, the implementation of a Programmable Logic Controller (PLC)-based control system allows for integrated operation of the RO unit, from pressure regulation, flow rate, to real-time monitoring of water quality. Important parameters such as Total Dissolved Solids (TDS), membrane pressure, and water discharge are monitored using sensors that are directly connected to the control system, so that any changes in conditions can be responded to immediately automatically.

Furthermore, the use of control methods such as PID controllers provides the system's ability to maintain process stability, especially in maintaining optimal pressure on the RO membrane. This is very important to prevent membrane damage and ensure that the quality of the filtered water remains according to industry standards.

In its implementation, the automation system is also equipped with protection features such as auto shutdown when there is a disturbance, as well as an automatic cleaning system (auto flushing and Cleaning in Place / CIP) which functions to extend the life of the membrane and maintain optimal system performance. With the development of technology, integration with the Internet of Things (IoT) increasingly allows the monitoring and control of the RO system to be carried out remotely, thereby increasing the flexibility and overall operational efficiency.

Although previous maintenance practices have been implemented, downtime in the RO unit still occurs and may disrupt production continuity. Problems such as membrane fouling, clogged filters, high-pressure pump failure, unstable water pressure, and electrical disturbances indicate that the existing maintenance system has not been fully optimal. Therefore, this study focuses on analyzing downtime patterns, identifying the main causes of machine failure, and evaluating the effectiveness of preventive and corrective maintenance in the RO unit. The results of this study are expected to provide practical recommendations for improving maintenance planning, reducing downtime, increasing machine reliability, and supporting the efficiency of the beverage production process.

Method

This study used a descriptive quantitative approach to analyze downtime and maintenance activities in the Reverse Osmosis (RO) unit at a beverage manufacturing company. The research was conducted for one month using primary and secondary data. Primary data were obtained through direct observation of RO unit operations and interviews with operators and technicians, while secondary data were collected from maintenance records, technician reports, machine logbooks, and monitoring data. The variables analyzed included downtime duration, failure causes, maintenance frequency, repair duration, and spare part availability. Data were analyzed by calculating total downtime, Mean Time To Repair (MTTR), Mean Time Between Failures (MTBF), and machine availability. Qualitative information from interviews and technician notes was used to support the interpretation of technical and procedural factors affecting RO unit performance.

Results and Discussion

The analysis showed that the Reverse Osmosis (RO) unit experienced 31 hours of downtime during 720 hours of operation. This indicates that although the machine was generally able to support production activities, downtime still occurred and affected operational efficiency. The main causes of downtime were membrane fouling, clogged pre-treatment filters, high-pressure pump problems, unstable water pressure, and electrical disturbances. Among these factors, membrane fouling became one of the most dominant problems because the accumulation of contaminants on the membrane surface reduced filtration efficiency and disrupted the stability of the RO system.

Machine Downtime Level

During the observation period, the Reverse Osmosis (RO) unit recorded 31 hours of downtime from a total of 720 operating hours. This condition indicates that the RO unit was generally still able to support production activities, but the occurrence of downtime shows that several technical and maintenance-related issues still affected operational efficiency. Although the downtime level was not extremely high, repeated machine stoppages can disrupt production flow, reduce equipment productivity, and increase operational costs. Therefore, downtime analysis is important to identify the dominant causes of machine failure and to determine appropriate maintenance actions to improve the reliability of the RO system.

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Main Causes of Downtime

Based on data analysis, we conclude that the main cause of downtime in RO units is membrane blockage. Basically, this happens when contaminants or solutes accumulate on the surface of the membrane, thereby disrupting the efficiency of the filtration system. Other factors that can interfere with the system include blockages in pre-treated filters, problems with high-pressure pumps, and fluctuations in water pressure.

The maintenance system of the RO unit at PT Minuman includes preventive and corrective maintenance.

Preventive maintenance is carried out through routine maintenance activities such as membrane cleaning, filter replacement, and pump pressure checks. Meanwhile, corrective maintenance is carried out when there are engine components that are damaged and need to be repaired or replaced. The study shows that routine preventive maintenance has been carried out; However, there are still some obstacles in adhering to maintenance schedules, which results in higher downtime.

Machine Reliability

Based on statistical calculations, the Mean Time To Repair (MTTR) was recorded at 2.58 hours, which indicates the average time required to repair a malfunction in the RO machine. The Mean Time Between Failures (MTBF) is 60 hours, which means the machine tends to experience problems approximately every 60 hours of operation.

The machine availability rate of 95.69% shows that the RO machine is quite reliable in maintaining smooth production.

5. Downtim's Impact on Production

When the RO unit experiences downtime, it can disrupt the entire production line, especially since we need pure water to produce beverages. If downtime occurs too often or lasts too long, it can disrupt the production flow and increase the company's operating costs.

Figure 3. Fouling of the membrane before and after repair

Figure 3 illustrates the condition of membrane fouling before and after repair. Before maintenance, the membrane showed signs of blockage caused by the accumulation of contaminants, which reduced permeate flow, increased pressure instability, and lowered filtration efficiency. After the repair and cleaning process, the membrane condition improved, as indicated by better water flow, more stable pressure, and clearer permeate quality. This finding confirms that membrane fouling was one of the main causes of downtime in the RO unit and that routine membrane cleaning is essential to maintain system performance.

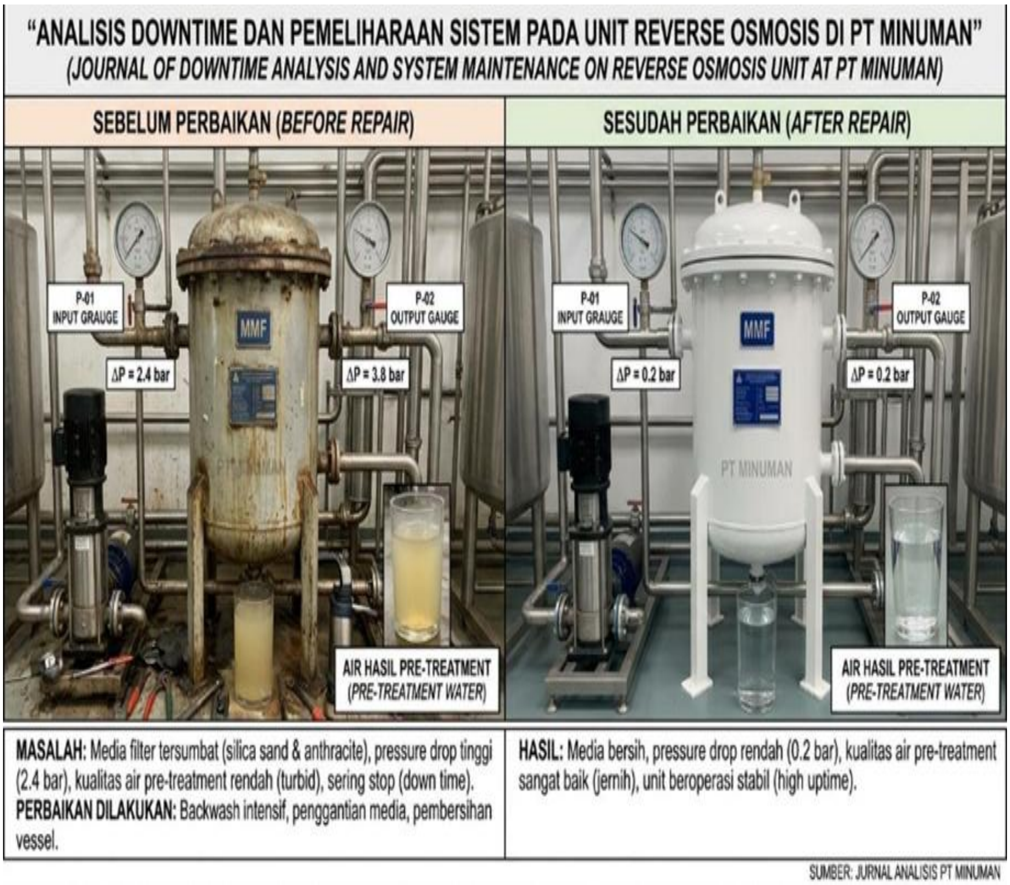

Figure 4. Pre-treatment filter clogged before and repair.

Figure 4 shows the condition of the pre-treatment filter before and after repair. Before maintenance, the filter was clogged and dirty, causing pressure drop and reducing the quality of water entering the RO membrane. This condition increased the workload of the RO system and contributed to potential membrane fouling. After filter replacement and cleaning, the water flow became smoother, pressure conditions improved, and the pre-treatment process operated more effectively. This indicates that regular inspection and replacement of pre-treatment filters are important to prevent downtime and protect the RO membrane.

Review: Journal of Multidisciplinary in Social Sciences

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Figure 5. High pressure pump breakdown before and after repair.

Figure 5 presents the condition of the high-pressure pump before and after repair. Before maintenance, the pump experienced performance problems, including unstable pressure and decreased pumping capacity, which affected the RO filtration process. Since the high-pressure pump plays a key role in pushing water through the membrane, any disturbance in this component can directly disrupt production continuity. After repair, the pump operated more stably, pressure returned to normal, and the RO system was able to function more efficiently. This shows that high-pressure pump maintenance is an important factor in reducing downtime.

Figure 6. The water pressure is not as stable before and after repairs.

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Figure 6 describes the condition of unstable water pressure before and after repair. Before improvement, water pressure fluctuated and caused instability in the RO process, which could reduce filtration quality and increase the risk of membrane damage. Unstable pressure also affected the consistency of water output and disrupted production reliability. After repair and system adjustment, the pressure became more stable, allowing the RO unit to operate under better process conditions. This result indicates that pressure monitoring and control are necessary to maintain RO system stability and prevent repeated downtime.

Figure 7. Electrical faults before repairs

Figure 7 shows electrical faults before and after repair. Before maintenance, several electrical components were in poor condition, which increased the risk of sudden shutdowns and disrupted the operation of the RO unit. Electrical disturbances can affect the control system, pump operation, and overall machine reliability. After repair, the electrical panel and components were improved, resulting in safer and more stable operation. This finding highlights the importance of routine electrical inspection as part of preventive maintenance to reduce unexpected downtime and support continuous production.

Conclusion

Based on the downtime and maintenance analysis of the Reverse Osmosis (RO) unit, it can be concluded that the performance of the RO system is strongly influenced by the effectiveness of the maintenance program. The main causes of downtime were membrane fouling, clogged filters, high-pressure pump failure, unstable water pressure, and electrical disturbances. During the observation period, the RO unit recorded 31 hours of downtime, with an MTTR of 2.58 hours, an MTBF of 60 hours, and an availability rate of 95.69%. These findings indicate that the RO unit is relatively reliable, but the maintenance system still requires improvement, particularly in preventive maintenance scheduling and early failure detection. To reduce downtime and improve operational efficiency, the company should strengthen preventive maintenance, conduct routine component inspections, and implement real-time monitoring systems. The use of PLC-based automation, PID control, and IoT-based monitoring can help detect potential failures earlier, maintain stable operating parameters, and support predictive maintenance. With a more planned and integrated maintenance strategy, the RO unit can operate more efficiently, production continuity can be maintained, and water quality can remain consistent with beverage industry standards.

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