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Aeration Ponds for Improved Wastewater Management at Universiti Teknologi MARA Johor Branch, Segamat Campus: A Quality Assessment

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ABSTRACT

UiTM Johor decided to upgrade its wastewater treatment plant from an oxidation pond to an aeration pond due to the increasing population and availability of sufficient funding. This study was conducted to evaluate the effectiveness of the aeration pond over a 12-month period and compare the results with those from previous 12 months of using the oxidation pond. The data was obtained from a contractor appointed by UiTM to operate the wastewater treatment plant. The study conducted at UiTM Segamat Campus collected data on several water quality parameters, including pH, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Oil and Grease, Ammonia Nitrogen, Nitrate Nitrogen, and Phosphorus. The results showed that the effectiveness of the aeration pond was comparable to that of the oxidation pond. However, several parameters, such as pH, COD, BOD, nitrate nitrogen, ammonia nitrogen, and TSS, were higher in the aeration pond compared to the oxidation pond. Despite this, all parameters studied complied with the Department of Environment (DOE) standards for both systems. Hence, further studies to improve the existing aeration pond to ensure long-term benefits for UiTM Johor in terms of energy consumption, maintenance, sludge management, and return on investment (ROI).

Keywords: aeration pond; BOD; oxidation pond; STP; wastewater

INTRODUCTION

According to the Environmental Quality (Sewage) Regulations 2009, wastewater management or sewage treatment system refers to any facility created for the purpose of reducing the potential of sewage that can cause pollution. These regulations apply to any premises that discharge sewage onto or into the soil, inland waters, or Malaysian waters, except for housing or commercial developments, or both, with a population equivalent of less than 150.

Wastewater, also known as sewage, contains various pollutants. These pollutants can be classified into physical, chemical and biological components (Davis, 2011, p. 12-7). Wastewater can pollute groundwater, canals and estuaries. This is why wastewater must be treated before being discharged into nearby rivers. Therefore, the treatment method must be appropriate for the population size and the budget allocated by the institution.

At UiTM Segamat Campus, the increasing student population has led to the necessity of upgrading the existing wastewater treatment system from an oxidation pond to a more efficient aeration pond. This transition was implemented to ensure that the treatment facility could effectively accommodate the rising volume of wastewater generated by the growing number of students and staff. The wastewater treatment plant at the campus is specifically designed to manage municipal wastewater, with no industrial effluent being discharged into the system, thereby ensuring that only domestic sewage is treated.

The operation of the wastewater treatment plant has been entrusted to different contractors, selected through a bidding process, where the contract is awarded to the bidder offering optimum operational cost consideration while still meeting the required regulatory standards. To ensure compliance with environmental regulations, monthly water quality tests are conducted to assess whether the treated effluent meets the Department of Environment (DOE) Malaysia's guidelines. These tests evaluate key water quality parameters to ensure that the effluent discharged from the treatment plant does not negatively impact the surrounding environment.

Given these considerations, the objective of this study is to evaluate the effectiveness of the aeration pond system in managing wastewater at UiTM Segamat Campus. The study aims to compare the performance of the aeration pond with the previous oxidation pond system, assessing key water quality indicators such as pH, chemical oxygen demand (COD), biological oxygen demand (BOD), total suspended solids (TSS), nitrate nitrogen, and ammonia nitrogen. By analyzing these parameters, this paper seeks to determine whether the transition to an aeration pond has resulted in improved wastewater treatment efficiency and enhanced compliance with environmental standards for the campus wastewater management system.

LITERATURE REVIEW

Wastewater treatment is essential for reducing environmental pollution and protecting public health. Among the various treatment methods, aeration systems and oxidation ponds are widely used due to their efficiency in organic matter degradation. Aeration and oxidation ponds are integral components of wastewater treatment, each employing distinct mechanisms to degrade organic matter and pollutants. Wastewater aeration is a process to treat contaminated water, where air is deliberately introduced to encourage the growth and activity of aerobic microorganisms. This technique utilizes oxygen to support the metabolic functions of bacteria, fungi and other microorganisms that thrive in oxygen-rich conditions. The increased microbial activity accelerates the breakdown of organic matter, reducing pollutant levels and producing cleaner, safer water.

The decision between aeration tanks and oxidation ponds is dependent on various factors, including budget constraints, available land area, desired treatment efficiency and environmental consideration. Aeration tanks are suitable for urban areas with limited space and require efficient treatment, despite higher operational costs. In contrast, oxidation ponds are ideal for rural areas with large land, offering a cost-effective and environmentally friendly alternative, although with longer treatment times and less operational control.

Oxidation pond system

An oxidation pond system, also known as a stabilization pond or lagoon, is a wastewater treatment method that relies on natural biological processes like sunlight, bacteria and algae to break down pollutants and purify water in large, shallow, open basins (Alexiou & Mara; 2003). It is considered as the secondary treatment method by which natural purification and stabilization of wastewater like domestic sewage, industrial effluents and trade waste is accelerated. The use of wastewater oxidation pond technology is among the most significant natural wastewater treatment techniques, as their effectiveness depends on sustaining a balanced microbial community including bacteria, viruses, fungi and protozoa (Hosetti & Frost, 1995).

Effectiveness and limitations of oxidation pond

According to Tharavathy et al. (2014), oxidation pond systems are most suited for treating nutrient-rich trade waste and household sewage in many tropical regions of the world with adequate sunlight and temperature. The biological treatment process in an oxidation pond primarily involves interactions between bacteria, algae and other species. This process effectively eliminates bacteria, nitrogen, phosphorus and biodegradable organics from wastewater before it is released into receiving streams. With this approach, wastewater Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and heavy metals in wastewater can frequently be reduced by 98% to 99%. In regions with sufficient sunlight and warm temperatures, oxidation ponds are considered one of the best options for treating domestic sewage and nutrient-rich industrial waste. However, in recent years, lifestyle changes, urbanization, industrial growth, and new technologies have increased the amount of pollution in wastewater. When such pollutants build up in the ponds, they can become toxic to organisms living in there. If the wastewater contains too many of these pollutants, it can overload the system, causing a sudden drop in treatment quality.

A study by Latip et al. (2022) discovered that the application of water hyacinth as a natural polishing agent enhanced the dissolved oxygen level on the water surface of the oxidation pond up to 12 mg/l and increased the COD removal percentage by 60% compared to the baseline, at 47%. The use of environmentally friendly water hyacinths in wastewater oxidation pond as polishing agent enabled the COD removal to meet the Malaysian Standard A for Sewage and Industrial Effluent Discharge. Therefore, introducing water hyacinths into oxidation ponds has strong potential to support domestic wastewater treatment. Moreover, implementing this eco-friendly approach in sewage treatment system could help reduce operational costs.

In the present study by Krimech et al. (2025), waste stabilization ponds can reduce BOD depends on the temperature. The efficiency of BOD removal is influenced by temperature with approximately 60% reduction achieved at 20°C, though it varies at different temperatures. However, the efficiency can be lower than 60% under suboptimal circumstances such as insufficient retention times, poor mixing or excessive organic loading rates. This study also highlights the need to improve treatment systems by removing scum and overgrown plants, such as grass, which can block water flow in the ponds. These improvements can produce high-quality reclaimed water, which is important for addressing water scarcity challenges.

Aeration pond system

Artificial aeration method enhances oxygen levels in stabilization tank, promoting aerobic microbial activity essential for effective wastewater treatment. In these tanks, the wastewater is mixed with a concentrated population of microorganisms, and oxygen is supplied through mechanical aeration system, such as diffused air or a mechanical surface aerator. Mechanical aeration provides a continuous and controlled supply of oxygen, ensuring optimal conditions for microbial activity.

Effectiveness and limitations of aeration pond system

The efficiency of the aeration pond system in lowering, especially BOD and COD content of wastewater using variety of techniques and concepts has been investigated in numerous studies. Chyan et al. (2016) found that incorporating artificial aeration and flow rectification in campus wastewater treatment significantly improved pollutant removal efficiency in free water surface constructed wetlands. This approach increased the BOD removal rate for low average concentrations (below 12.3mg/L) from 46.7% to 68.3% on school days, and from 13.2% to 46.7% on non-school days. Since the incoming water had low BOD levels, aeration helped remove almost three times more BOD compared to system without aerations. Aeration also increased the system's treatment capacity, meaning less space and lower cost needed. However, in systems without proper flow control, aeration stirred up sediments which worsen BOD and ammonia removal, although it slightly improved total phosphorus removal by increasing particle settling and absorption.

In wastewater treatment, aeration consumes the most energy, accounting for 45% to 75% of plant energy expenses (Rosso et al., 2008), making itit the most expensive procedure used by treatment plants. A study by Aytac et al. (2024) successfully developed and optimized a high-head gated conduit aeration system for pond aeration, focusing on maximizing aeration efficiency while minimizing energy consumption. The system demonstrated a significant improvement in water circulation; with over three times the unit volume being recirculated. Moreover, the energy cost was measured at 0.10 kWh/m^3 air, indicating superior energy efficiency compared to existing aeration alternatives.

According to De Mendonça et al. (2025), sustaining the performance of aeration pond wastewater treatment systems, requires, long-term monitoring and timely maintenance. The study highlights the long-term effectiveness of integrating an aerated facultative lagoon with a subsurface flow constructed wetland. Over a 10-year monitoring period, the system demonstrated high pollutant removal efficiency, achieving over 98% removal of COD, BOD and TSS. However, significant clogging and surface flow issues emerged in the seventh year caused a drop in treatment efficiency, suggesting that this is the recommended maximum operating period for constructed wetlands used after an aerated facultative lagoon in the dairy industry.

METHODOLOGY

This study focuses on sewage treatment plants (STP) located in *UiTM Cawangan Johor Kampus Segamat* (UiTMCJKS). UiTMCJKS enrolls a maximum of 2500 students per semester, with two semesters per year: March – July and October-February. The locations of STP system of UiTMCJKS for previous STP oxidation pond (OP) (2.4860094554376504, 102.73162198379742) and the current STP extended aeration (EA) system (2.4868455167625334, 102.73367119144615) are shown in Figure 1.

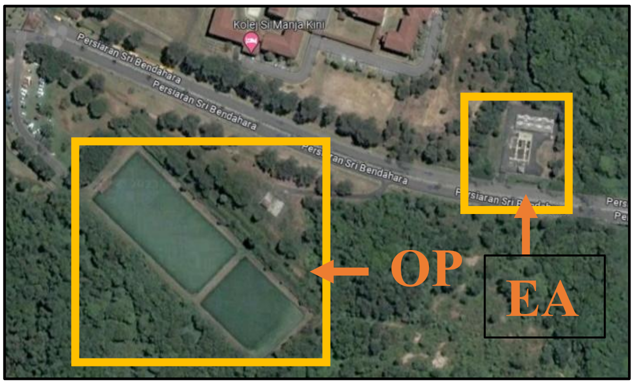

Figure 1. Location of STP UiTMCJKS

The STP is designed for a population equivalent (PE) of 3000. The treated effluent will be discharged into Sungai Penarah and must comply with Water Quality Standard B. The main objective of this study is to evaluate the effectiveness of the EA system at UiTMCJKS in meeting the requirements of Standard B.

This study incorporated the technical drawing of STP and the existing effluent monitoring procedures, with permission from the Facilities and ICT Management Office, UiTM Johor Branch. The STP design was first obtained, followed by the water quality test results from the appointed consultant. Hasrat Prestij Sdn Bhd was appointed to conduct water quality testing for both the Oxidation Pond (OP) and the Extended Aeration (EA) systems Figure 1 and Figure 2 display the top views of the oxidation pond (used in the old STP system) and the aeration pond (currently in operation) at UiTM Segamat Campus.


Figure 2. Top view of oxidation pond in UiTM Segamat Campus


Figure 3. Top view of aeration pond in UiTM Segamat Campus

Grab sampling was employed to collect water samples, which were gathered in the morning (from 7:00 a.m. to 8:00 a.m.) at effluent point to examine variations in physicochemical parameters throughout the day. The samples were collected manually, by dipping a clean bottle into the effluent point source in Figure 4.

Figure 4. Process of sample collection at effluent point source

Water samples were stored in four plastic bottles and two glass bottles with a volume of 0.5 liters in Figure 5. The sample collection and preservation procedures followed the guidelines outline in the APHA (American Public Health Association) Method. Monthly sampling was conducted by the appointed contractor for monitoring purposes. The samples were then tested in the laboratory according to the procedures outlined in Table 1, which lists the measured parameters and their corresponding standard methods, based on the Standard Methods for the Examination of Water and Wastewater.

Figure 5. Glass bottle is for submission to the laboratory for analysis

Table 1. Measure parameters and its standard method for both OP and EA System.

Parameter	Unit	Method	Standard B
Ph Value	-	APHA 4500-H$^+$B	5.5 – 9.0
Biochemical Oxygen Demand	mg/L	APHA 5210B/APHA 4500-OG	50
Chemical Oxygen Demand	mg/L	APHA 5220 C	200
Total Suspended Solids	mg/L	APHA 2540 D	100
Oil and Grease	mg/L	APHA 5520 B	10
Ammonial Nitrogen	mg/L	APHA 4500-NH_3C/ APHA 4500-NH_3B	20
Nitrate Nitrogen	mg/L	In-house Method VI	50
Phosphorus	mg/L	APHA 4500 - PC	10

RESULTS AND DISCUSSION

The study at UiTM Segamat Campus collected data on several water quality parameters, including pH, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Oil and Grease, Ammonia Nitrogen, Nitrate Nitrogen, and Phosphorus. Data for the oxidation pond was collected from January 2021 to May 2022, while data for the aeration pond were recorded from September 2022 to August 2023. Each dataset covers a 12-month period to compare the effectiveness and compliance of both systems with the established guidelines, as presented in Table 2.

The data was obtained from the contractor appointed by UiTM to operate the sewage treatment plant (STP) at UiTM Segamat Campus. Overall, the results show that both the oxidation pond and the aeration pond complied with the required standards.

Table 2. Data for pH, BOD, COD and TSS for oxidation pond and aeration pond

OXIDATION POND					AERATION POND				
Date	pH	BOD (mg/L)	COD (mg/L)	TSS (mg/L)	Date	pH	BOD (mg/L)	COD (mg/L)	TSS (mg/L)
Jun-21	6.70	7.00	82.00	11.00	Sep-22	6.90	6.00	57.00	11.00
Jul-21	6.50	10.00	71.00	9.00	Oct-22	6.20	6.00	41.00	11.00
Aug-21	6.80	6.00	45.00	7.00	Nov-22	6.70	5.00	21.00	10.00
Sep-21	6.40	8.00	41.00	10.00	Dec-22	6.20	13.00	53.00	14.00
Oct-21	6.40	9.00	67.00	10.00	Jan-23	6.40	17.00	81.00	16.00
Nov-21	6.60	4.00	28.00	6.00	Feb-23	7.00	11.00	60.00	17.00
Dec-21	6.90	6.00	53.00	12.00	Mac- 23	6.70	8.00	60.00	11.00
Jan-22	6.90	9.00	56.00	8.00	Apr-23	6.80	15.00	65.00	15.00

Table 2. (continued)

Feb-22	7.00	9.00	52.00	8.00	May-23	6.90	11.00	62.00	13.00
Mar-22	6.70	4.00	50.00	7.00	Jun-23	7.00	12.00	52.00	12.00
Apr-22	6.70	5.00	42.00	9.00	Jul-23	7.20	14.00	81.00	12.00
May-22	5.60	9.00	41.00	13.00	Aug-23	6.90	10.00	58.00	13.00
Average	**6.60**	**7.17**	**52.33**	**9.17**	**Average**	**6.74**	**10.67**	**57.58**	**12.92**

The effectiveness of both the oxidation pond and the aeration pond at UiTM Segamat Campus was evaluated based on the trends and variations in key water quality parameters: pH, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Total Suspended Solids (TSS). The analysis is based on a 12-month data collection period for each system. For the oxidation pond, TpH levels ranged from 5.60 to 7.00, with an average of 6.60. The lowest pH value (5.60) recorded in May 2022 suggests a temporary drop that could indicate occasional acidification. Meanwhile, the pH levels were slightly more stable, ranging from 6.20 to 7.20, with an average of 6.74 for aeration pond. The pH remained within a more neutral range, which is favorable for microbial activity essential for wastewater treatment. Although, both systems maintained pH levels within acceptable limits for biological wastewater treatment, the aeration pond showed slightly better pH stability, potentially enhancing microbial efficiency in degrading organic matter.

BOD levels in the oxidation pond varied from 4.00 mg/L to 10.00 mg/L, with an average of 7.17 mg/L. The relatively lower BOD values suggest that the oxidation pond was effective in treating the organic load under normal conditions. In comparison, the aeration pond recorded BOD levels between 5.00 mg/L to 17.00 mg/L, with a higher average of 10.67 mg/L. The higher values, especially in January 2023 (17.00 mg/L) and April 2023 (15.00 mg/L), indicate fluctuations in organic matter content or challenges in treatment efficiency, possibly due to increased population or loading variations. The aeration pond, while capable of handling higher loads, displayed variability in BOD levels.

COD levels ranged from 28.00 mg/L to 82.00 mg/L, with an average of 52.33 mg/L for oxidation pond. The lower COD values reflect effective breakdown of organic compounds in the pond. COD levels showed a wider range from 21.00 mg/L to 81.00 mg/L, with an average of 57.58 mg/L. Despite a generally comparable performance to the oxidation pond, higher peaks in COD (such as 81.00 mg/L in January 2023) suggest intermittent increases in organic and inorganic pollutants. The aeration pond's performance in reducing COD is comparable to that of the oxidation pond but with occasional spikes, indicating potential operational or loading issues. Continuous monitoring and adjusting treatment parameters will be key to maintaining consistent performance.

TSS levels were consistently low, ranging from 6.00 mg/L to 13.00 mg/L, with an average of 9.17 mg/L for oxidation pond. Meanwhile, the aeration pond recorded TSS levels slightly higher, ranging from 10.00 mg/L to 17.00 mg/L, with an average of 12.92 mg/L. The higher TSS levels in the aeration pond could be attributed to greater turbulence or the release of solids from microbial activity. The higher TSS in the aeration pond suggests that the aeration process may be causing an increased suspension of particles. This may require additional settling time or filtration steps to ensure that effluent TSS levels remain within acceptable standards.

Table 3. Data for Oil & Grease, Ammonial Nitrogen, Nitrate Nitrogen, Phosphorus for oxidation pond and aeration pond

AXIDATION POND					AERATION POND				
Date	Oil & Grease (mg/L)	Ammonial Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Phosphorus (mg/L)	Date	Oil & Grease (mg/L)	Ammonial Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Phosphorus (mg/L)
Jun-21	ND <1	7.80	2.06	1.73	Sep-22	ND <1	2.50	1.60	1.20
Jul-21	ND <1	7.80	3.26	1.77	Oct-22	ND <1	2.40	2.40	1.40
Aug-21	ND <1	2.10	1.75	1.04	Nov-22	ND <1	4.30	1.70	1.20
Sep-21	ND <1	4.90	2.65	1.85	Dec-22	ND <1	8.10	2.60	1.70
Oct-21	ND <1	6.80	2.43	1.71	Jan-23	ND <1	5.80	2.50	0.80
Nov-21	ND <1	6.80	1.48	0.52	Feb-23	ND <1	6.60	2.70	1.20
Dec-21	ND <1	4.90	2.64	1.79	Mac-23	ND <1	3.20	1.50	1.30

Table 3. (continued)

	ND <1	4.70	1.67	0.78	Apr-23	ND <1	5.00	2.50	1.10
Feb-22	ND <1	6.50	1.75	0.95	May-23	ND <1	5.60	2.50	1.90
Mar-22	ND <1	5.50	1.75	1.22	Jun-23	ND <1	15.00	2.51	1.03
Apr-22	ND <1	3.40	1.45	0.66	Jul-23	ND <1	4.00	2.54	1.14
May-22	ND <1	5.50	1.43	0.88	Aug-23	ND <1	11.00	1.90	0.97
Average	**ND <1**	**5.56**	**2.03**	**1.24**	**Average**	**ND <1**	**6.13**	**2.25**	**1.25**

Based on Table 3, both the oxidation pond and the aeration pond effectively removed Oil & Grease from the wastewater, as evidenced by the non-detection of these compounds. This suggests that both systems are highly efficient in removing oil and grease, which is critical for preventing potential environmental pollution and system malfunctions.

Ammonia Nitrogen levels ranged from 2.10 mg/L to 7.80 mg/L, with an average of 5.56 mg/L for the oxidation pond. Meanwhile, the aeration pond recorded Ammonia Nitrogen levels between 2.40 mg/L to 15.00 mg/L, with an average of 6.13 mg/L. The oxidation pond generally had lower levels of Ammonia Nitrogen compared to the aeration pond. The higher average in the aeration pond, especially with peaks such as 15.00 mg/L in June 2023, indicates that ammonia removal might be less efficient in the aeration pond under certain conditions. The higher levels of Ammonia Nitrogen in the aeration pond could be attributed to the increased organic load or operational inefficiencies. It may be necessary to assess and optimize aeration rates or adjust treatment processes to enhance ammonia removal efficiency.

Nitrate Nitrogen levels ranged from 1.43 mg/L to 3.26 mg/L, with an average of 2.03 mg/L for the oxidation pond. Meanwhile, the aeration pond recorded Nitrate Nitrogen levels between 1.60 mg/L to 2.70 mg/L, with an average of 2.25 mg/L. Both ponds effectively reduce nitrate levels, with the aeration pond showing slightly higher average nitrate nitrogen. This difference could be due to the different treatment efficiencies or nitrification processes between the systems. The generally low nitrate levels in both systems suggest that the wastewater treatment processes are effective in reducing nitrogenous compounds, which helps in mitigating potential environmental impacts.

Phosphorus levels ranged from 0.52 mg/L to 1.85 mg/L, with an average of 1.24 mg/L for the oxidation pond. Meanwhile, the aeration Pond recorded Phosphorus levels between 0.80 mg/L to 1.90 mg/L, with an average of 1.25 mg/L. The phosphorus levels in both ponds are relatively comparable, with the aeration pond having slightly higher average phosphorus levels. This indicates that both systems are similarly effective in phosphorus removal, though the aeration pond might require additional phosphorus removal strategies if higher levels persist. Phosphorus removal is crucial for preventing eutrophication in receiving water bodies, so continued monitoring and optimization of phosphorus removal processes are important.

CONCLUSIONS

The transition to an aeration pond at UiTM Segamat Campus was necessary to accommodate the increased wastewater load due to a growing population. While both treatment methods meet regulatory standards, the aeration pond requires careful monitoring and optimization to ensure consistent performance. Future adjustments and continuous monitoring will be key to maximizing the effectiveness of the aeration pond system. The key summary of the findings is as follows:

(i) Both ponds maintain acceptable pH levels, with the aeration pond being slightly higher.
(ii) The aeration pond's higher BOD levels suggest higher organic loads and variability in treatment efficiency.
(iii) The aeration pond exhibits higher and more variable COD levels, pointing to higher organic loads and potential treatment inefficiencies.
(iv) The aeration pond has higher TSS levels, indicating a need for better solids management.
(v) Both the oxidation and aeration ponds effectively remove oil and grease, with consistent non-detection across all data points.

(vi) The oxidation pond generally achieved lower ammonia nitrogen levels compared to the aeration pond. The aeration pond showed higher variability and peak levels.
(vii) Both ponds effectively reduce nitrate nitrogen, though the aeration pond shows slightly higher levels on average. This indicates that both systems are efficient in nitrification.
(viii) Phosphorus levels are similar in both ponds, with slight differences in average concentrations. Both systems are effective in phosphorus removal.

To enhance the performance of the oxidation and aeration ponds, the following improvements are recommended based on recent data: For the aeration pond, which shows higher and more variable TSS and BOD levels compared to the oxidation pond, implementing enhanced solids removal systems and optimizing aeration processes are crucial. Regular monitoring and adjustment of pH levels should be maintained for both ponds to ensure stability. Addressing high COD peaks in the aeration pond through better management of aeration rates and pre-treatment processes is also essential. Additionally, operational optimization, increased monitoring and maintenance, potential system upgrades, and staff training will contribute to improved treatment efficiency and compliance with regulatory standards.

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CONFLICT OF INTERESTS

This article is based on data obtained from the infrastructure & infostructure division and has not been submitted to any other publishers.

AUTHORS' CONTRIBUTIONS

The authors confirm contribution to the paper as follows: study conception and design: Narita Noh; data collection: Maznah Salamin; analysis and interpretation of results: Juwita Asfar, Noor Raifana Ab Rahim; Methodology; Nur Zaidani Wati Mohd Darwis draft manuscript preparation: Narita Noh, Juwita Asfar, Nur Zaidani Wati Mohd Darwis, Noor Raifana Abd Rahim. All authors reviewed the results and approved the final version of the manuscript.

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