Performance Evaluation of Compact Water Treatment System Pilot Project at Timah Tasoh Water Treatment Plant, Perlis, Malaysia

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ABSTRACT

The importance of clean and safe water for the well-being of the population is paramount, especially with the increasing demand attributed to the population growth in Perlis state. This study evaluates the performance of the Package Timah Tasoh Water Treatment Plant, a crucial infrastructure designed to meet the increasing demand for clean and safe water in the state of Perlis, Malaysia. The plant employs a Compact Water Treatment System, deviating from existing conventional plant system, and operates under Category B, a plant with a design that does not fall under the specifications according to SPAN guidelines. Focusing on adherence to Ministry of Health (MOH) standards, the research monitors twelve water quality parameters over a three-month period. Average results indicate that eight parameters such as pH, TDS, turbidity, colour, Aluminium, Iron, Manganese and Ammonia consistently meet drinking water standards, with removal efficiencies ranging from 22% to 77%. However, challenges persist in chlorine residual, fluoride, Standard Total Coliform, and E. coli compliance. The inoperability of the disinfection process contributes to non-compliance, emphasizing the need for ongoing assessments and improvements. Despite challenges, the overall performance underscores the plant's effectiveness in delivering safe and potable water, contributing vital insights for water treatment advancements. The study recommends continuous research and monitoring to address non-compliant parameters and ensure sustained water quality in response to population growth.

Keywords: Water treatment plant, compact system, water quality parameters, performance evaluation.

1. INTRODUCTION

Water is an indispensable resource crucial for sustaining human life and supporting the vitality of various organisms. Despite its paramount importance, contemporary challenges such as clean water scarcity persist in many regions, exacerbating the global demand for clean and safe water supplies. Besides, the escalating demand for water, driven by urbanization, economic growth, and industrial development, poses a significant challenge too [1]. This clean and safe water issue not only threatens public health but also poses a considerable risk, with approximately 80% of global illnesses attributed to inadequate sanitation or the absence of access to safe water, as reported by the World Health Organization (WHO) [2]. Addressing these challenges aligns with the United Nations' Sustainable Development Goal 6 (SDG 6), emphasizing the universal accessibility of safe water and sanitation management by 2030 [3].

Malaysia, heavily reliant on surface waters for its water supply, thus the need for diverse and efficient water treatment methods tailored to the quality of available water sources is pivotal to be highlighted [1]. The state of Perlis, marked by a high population density, experiences a continual rise in clean water demand, outpacing the capacity of existing water treatment plants. To address this, the federal government and water authorities embark on a strategic plan,

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upgrading the Timah Tasoh water treatment plant and introducing the 40 MLD Package Timah Tasoh Water Treatment Plant to meet the growing demand.

The compact design of the package treatment plant, categorized under Category B, necessitates ongoing performance evaluations and standardization processes before SPAN product registration [4]. This involves a rigorous assessment of water quality parameters in alignment with the drinking water quality standards set by the Ministry of Health (MOH) in Malaysia. The plant's distinctive features, deviating from conventional processes in terms of the design, technology, and quantity of unit operations, highlight the importance of continuous monitoring, maintenance efficiency, and space-saving initiatives. This study provides valuable perspectives on the performance of the Timah Tasoh Package Water Treatment Plant, focusing specifically on water quality and efficiency. It offers insights into how well the plant aligns with regulatory MOH standards and its overall effectiveness in providing high-quality potable water.

2. MATERIALS AND METHODS

2.1 Location of Study

In this research, the focus was on the Timah Tasoh Water Treatment Plant, chosen as the study area, utilizing raw water sourced from Timah Tasoh Dam in Perlis. This surface water reservoir is situated approximately 13 km north of Kangar town, near the Thailand border, boasting an average surface area of 13.33 square kilometers and a capacity of 40 million cubic meters [5]. Figure 1 illustrates the location of the Timah Tasoh Water Treatment Plant, alongside the existing conventional and package plants.

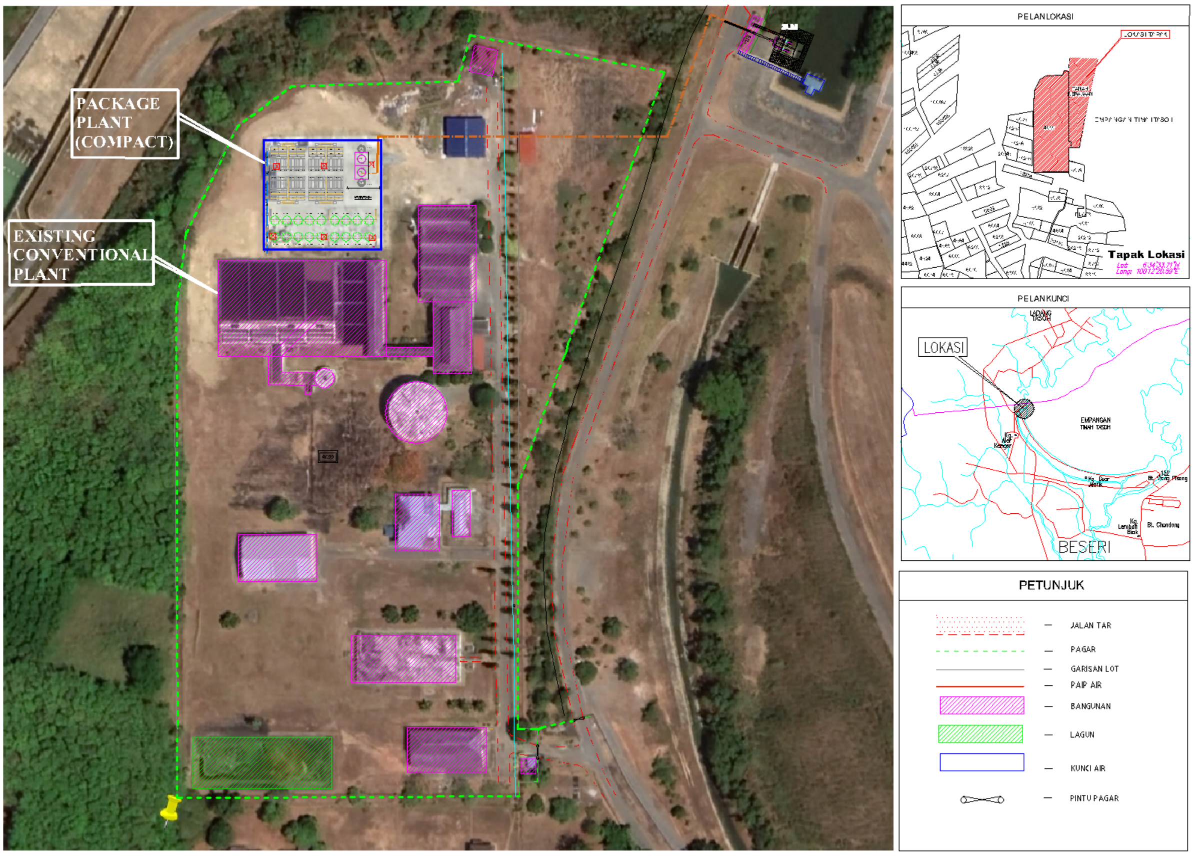

Figure 1. Location of Timah Tasoh Water Treatment Plant, Perlis.

2.1.1 Package Timah Tasoh Water Treatment Plant

The compact 40 MLD capacity package plant was situated adjacent to the conventional Timah Tasoh Water Treatment Plant. Both plants drew water from Timah Tasoh Dam, necessitating synchronized operations to enhance water quality. The Package Timah Tasoh Water Treatment Plant utilized a streamlined system incorporating aeration, flocculation/coagulation, clarification, and filtration processes. Operating within a compact system, it employed a minimal number of unit operations, including two aerators and mixing chambers, sixteen flocculation and clarification tanks, and eighteen filters. This design, with dimensions of 48 m x 51 m on a concrete base, not only conserved space but also facilitated plant maintenance. The plant was operated with 20 – 30 MLD operation capacity. The chemical used in this treatment system were the coagulant ACH (Aluminium Chlorohydrate) for the first 8 weeks and then PAC Type II (Polyaluminum Chloride) used, specifically chosen for the flocculation process.

2.2 Sampling Points

On-site water sampling was conducted at four designated points: a) P1: Raw water (RW) sourced from Timah Tasoh Dam, b) P2: Settled water (SW) sampled at the outlet pipe of clarification units, c) P3: Filtered water (FW) collected from the outlet pipe of filtration units, and d) P4: Treated water (TW) obtained after the disinfection process, just before entering the clean water tank [6]. It's essential to note that the disinfection process occurred solely in the pipeline of treated water produced by the existing conventional water treatment plant. The positioning of these four sampling points within the Package Timah Tasoh Water Treatment Plant is illustrated in Figure 2.

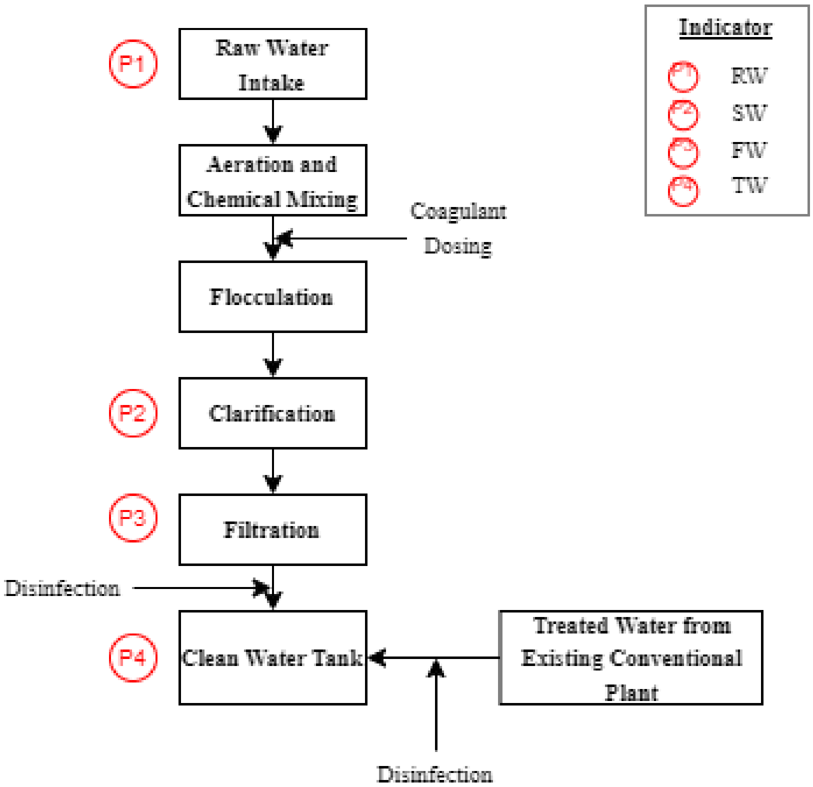

Figure 2. Location of four sampling points; P1: RW, P2: SW, P3: FW and P4: TW.

2.3 Data Collection Analysis

Water collected from the sampling tap (faucet) underwent a one-minute flushing to eliminate any impurities or residues on the tap [6]. Subsequently, the water was stored in 1L plastic bottles with caps for sample analysis. Sampling activities were preliminarily conducted over three months, spanning from October to December 2022, with a weekly frequency. The sample analysis took place in a certified laboratory, covered twelve specific parameters, including turbidity, pH, TDS, color, Ammonia, residual chlorine, Aluminium, Iron (Fe), Manganese (Mn), fluoride, Standard Total Coliform, and E. coli [6][7]. These parameters were assessed according to the American Public Health Association (APHA), Standard Method for Examination of Water and Wastewater, 21st Edition, 2005 [8]. Then, these water quality parameters were examined to assess the plant's performance, primarily focusing on TW quality with the drinking water quality standards by MOH [9]. The removal efficiency of each parameter was evaluated by comparing the influent and effluent of the sampled water, providing an overview of the overall performance, as depicted in Equation (1) [6]. Moreover, operational and maintenance records were reviewed to obtain additional insights into the overall performance of the compact system in the package plant.

$$\text{Removal Efficiency, \%} = (\text{Parameter}_{\text{Influent}}\ \text{Parameter}_{\text{Effluent}})/\text{Parameter}_{\text{Influent}} \times 100\% \quad (1)$$

3. RESULTS AND DISCUSSION

3.1 Water Quality Parameters

3.1.1 pH

The pH serves as an indicator as it influences the dosages of added chemicals needed for coagulating particles [10]. The pH data for all water types consistently falls within the range of 7 to 8, aligning with the pH standards set by the MOH (6.5–9.0), as in Figure 3. Consequently, there is no need for pH adjustments, as the dataset consistently reflects values within the acceptable range.

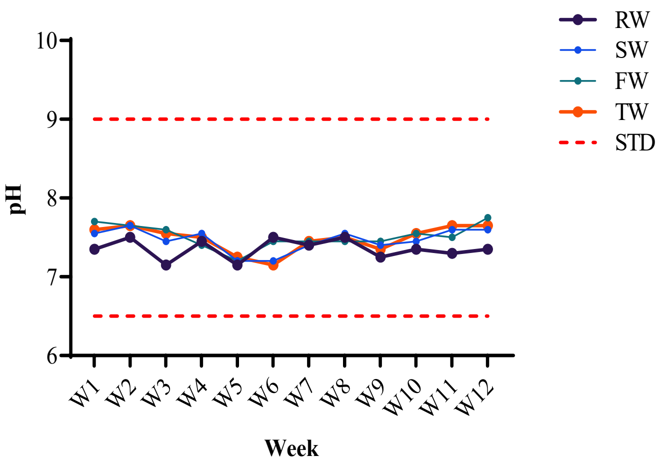

Figure 3. pH data over time.

3.1.2 Turbidity

Based on the Figure 4, the average turbidity data for TW in W1 is slightly violated the standards, where the average SW turbidity showcased a higher value (>40 NTU) compared to RW due to the poor performance of flocculation and clarification processes. According to the operation record, coagulant ACH is used initially from W1 to W8, with inoperative flocculator, affecting settling speed in the flocculation tank which led to suboptimal floc formation [11], resulting in an increase in turbidity parameters of SW. The inoperability of the flocculator caused subsequent mixing processes to be less effective, even though the coagulant had been dosed in the mixing tank. After W8, appropriate flocculator setting rectified. Then PAC was utilized and jar test performed, as in the record. As in overall, 96% of the samples complied to the MOH drinking water quality standard.

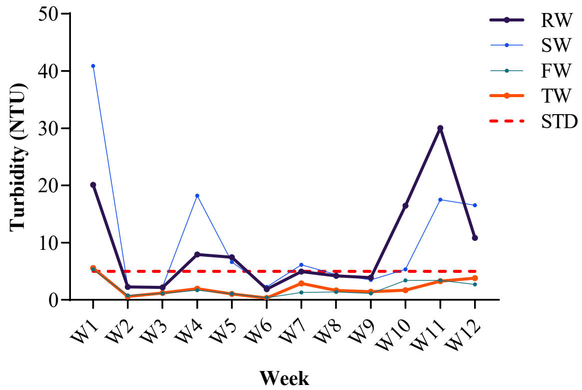

Figure 4. Turbidity data over time.

3.1.3 Colour

Figure 5 represented a stable dataset of colour parameters yet depicted the non-compliance of 25% of the TW samples. Sources of color in water may encompass natural metal ions (such as iron and manganese), humic and fulvic acids, lignin, tannin, algae, peaty substances, planktons, ferric and sulfuric bacteria, which can be removed via several processes including conventional coagulation, flocculation and filtration processes [12]. However, the elimination of colour proved ineffective when confronted with high colour values as in RW W10. Similarly, high value of iron detected on W10 as well as in Figure 8.

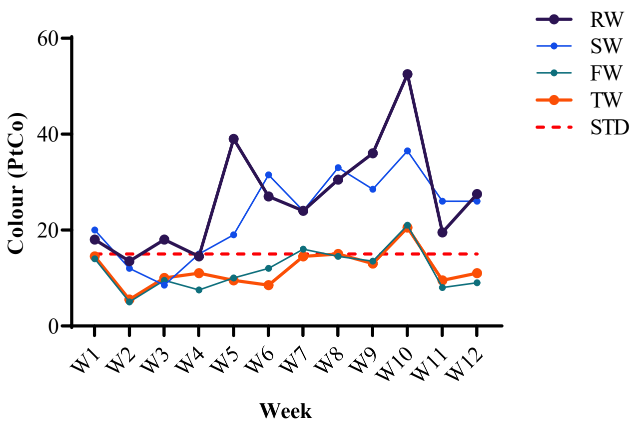

Figure 5. Colour data over time.

3.1.4 TDS

The TW data consistently falls within the range of 50 – 100 mg/L demonstrated in Figure 6. The TDS parameter indicates the presence of organic or inorganic substances in the water. The permissible drinking water quality standard set by the MOH is below 1000 mg/L. Therefore, the TDS dataset for TW is considered stable and reliable as it complies with the established standards despite of inconsistent values of all water samples.

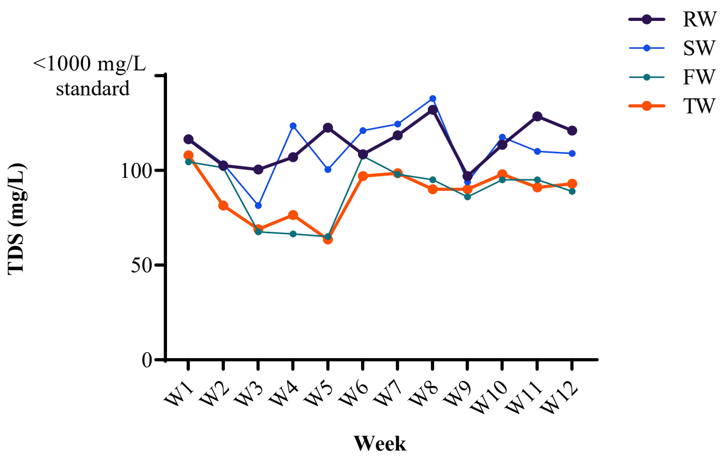

Figure 6. TDS data over time.

3.1.5 Aluminium

Figure 7 displays the fluctuating and unreliable nature of the Aluminum dataset, with instances of non-compliance in water samples to the set standards (only 78% of the samples in agreement with the standards), especially when the Aluminum concentration is high in RW. Generally, the effect of aluminum in water is caused by excessive chemical doses. The switch of coagulant chemicals for the flocculation process from ACH to PAC Type II impacting water quality, particularly in terms of aluminum parameters that gradually increased following this change [13].

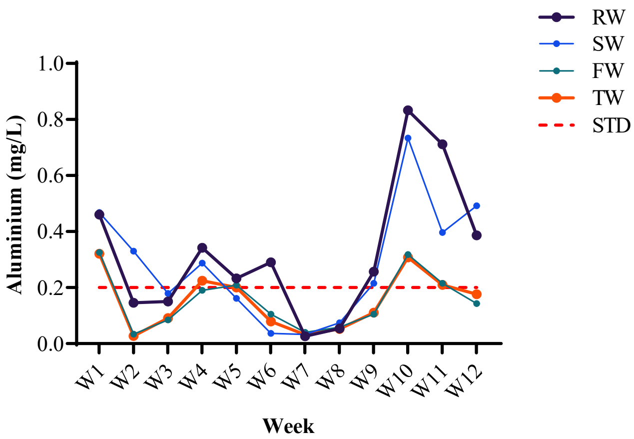

Figure 7. Aluminium data over time.

3.1.6 Iron

The dataset for the Iron parameter remains consistent and reliable (<0.3 mg/L MOH standards) throughout the monitoring period, as depicted in the Figure 8 below.

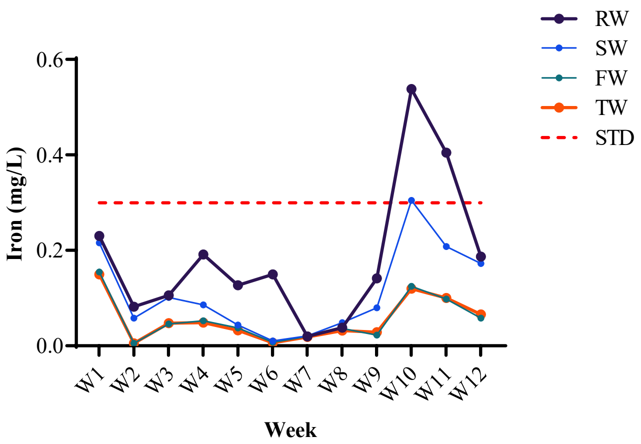

Figure 8. Iron data over time.

3.1.7 Manganese

Based on Figure 9, the datasets for Manganese were stable and reliable too throughout the testing period. This indicates that the Manganese parameter adheres to the established standard units and does not show significant values, especially during critical periods.

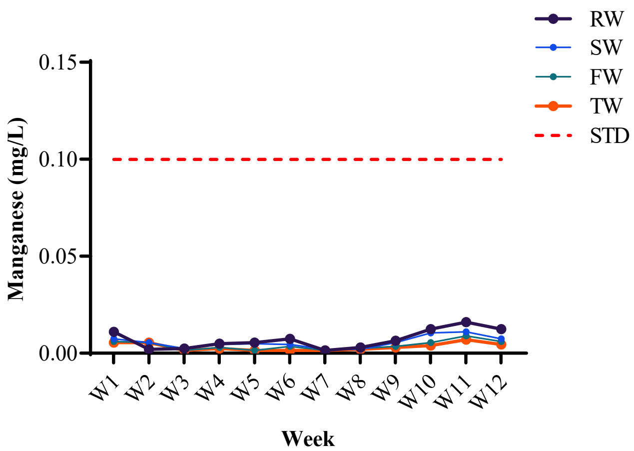

Figure 9. Manganese data over time.

3.1.8 Standard Total Coliform

The dataset for Standard Total Coliform in TW falls within the range of 11.5 to 52 MPN/100mL, as in Figure 10 signifying that the drinking water does not meet the required quality standards for microbiological parameters. Although there was a 0.96-log (89%) reduction in total coliforms from raw water, it did not reach the desired 2-log or 99% removal [6]. The non-compliance with Standard Total Coliform data is attributed to the non-operation of the disinfection process, which is performed at the existing conventional plant only.

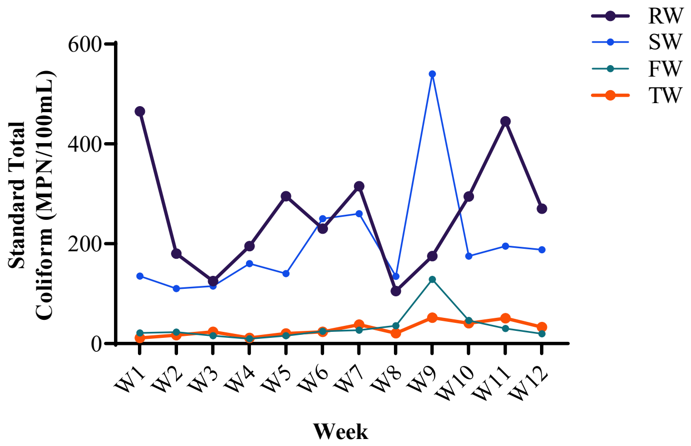

Figure 10. Standard Total Coliform data over time.

3.2 Overall Average and Removal Efficiencies

Table 1 depicted the water quality parameters measured in both RW and TW at the Package Timah Tasoh Water Treatment Plant, along with the corresponding Drinking Water Quality Standards set by MOH in Malaysia and the overall removal efficiency percentages. Eight of the water quality parameters such as pH, TDS, colour, turbidity, Iron, Manganese, Aluminium and Ammonia demonstrated compliance to the standards with respective removal efficiency. Whereas chlorine residual, fluoride, Standard Total Coliform and E. coli were not in agreement due to the inoperability of disinfection process at the facility yet.

Table 1 Overall average data and removal efficiencies

Parameter	Unit	Overall Average Data		MOH Std	Efficiency %
		RW	TW		
pH	-	7.4	7.5	6.5-9.0	-
TDS	mg/L	114.0	88.0	<1,000	22
Colour	PtCo	26.7	12.1	<15	55
Turbidity	NTU	9.3	2.1	<5	77
Fe	mg/L	0.2	0.1	<0.3	70
Mn	mg/L	0.007	0.003	<0.1	53
Al	mg/L	0.3	0.2	<0.2	53
Std Total Coliform	MPN/100ml	257.9	28.6	0 in 100 mL	89
Ammonia	mg/L	0.2	ND < 0.1	<1.5	NA
Chlorine Residual	mg/L	ND <0.1	ND < 0.1	0.2-5.00	NA
Fluoride	mg/L	0.1	ND < 0.1	0.4-0.6	NA
E.Coli	MPN/100ml	2.9	NG < 1.8	0 in 100 mL	NA

4. CONCLUSION

In conclusion, the performance evaluation of the Package Timah Tasoh Water Treatment Plant accentuated its effectiveness in delivering safe and potable water to consumers. While adhering to MOH standards for eight key parameters, including pH, TDS, color, turbidity, Iron, Manganese, Aluminium, and Ammonia, the package plant achieves removal efficiencies ranging from 22% to 77%. However, standards were not met for chlorine residual, fluoride, Standard Total Coliform, and E. coli, primarily due to the inoperability of the disinfection process. Despite the non-compliance, the overall removal efficiencies and compliance rates emphasize the plant's commendable performance to deliver safe and potable water to consumers. These findings contribute essential information for the ongoing assessment and enhancement of water treatment processes at the facility. Continuous research and monitoring are recommended to address non-compliant parameters and further enhance treatment processes. The study contributes valuable insights for ongoing assessments and improvements, providing a foundation for ensuring the sustained delivery of high-quality water to meet the rising demands of the population.

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