Assessment of Treated Sewage Effluent as an Alternative Clean Water Source for Car Wash Applications

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ABSTRACT

Sewage treatment is a critical process for ensuring that wastewater is treated to meet regulatory discharge standards. However, further polishing of the treated effluent is often required for applications such as vehicle washing, where water quality must meet specific criteria to prevent harm to users and potential damage to vehicles. This study evaluates the quality of treated effluent from a dedicated Sewage Treatment Plant (STP) after undergoing various post-treatment processes. Key parameters for physical, chemical, and biological, were analyzed to assess the suitability of the polished water for vehicle washing, referencing national drinking water standards as a benchmark. Review showed that the quality of the treated water for the targeted application should meet the national water quality standards (NWQS) Class I at the minimum, however best practice to follow drinking water quality standards. The turbidity, biological oxygen demand (BOD), chemical oxygen demand (COD), Ammonia nitrogen, oil and grease as well as e-coli/total coliform are parameters that do not meet the requirements upon treatments other than reverse osmosis. It is also confirmed that the membrane-based treatments, particularly RO, significantly improve water quality compared to conventional biological processes. RO-treated water exhibited characteristics comparable to local potable tap water, with complete removal of bacterial contaminants, confirming its safety for direct contact applications. In conclusion, integrating advanced membrane technologies such as ultrafiltration (UF) and RO into STPs can produce high-quality effluent suitable for vehicle washing without adverse effects. Several samplings and water quality analyses of the RO treated water have verified the consistency of the water quality that meets the drinking water standards. This study could serve for sustainable development goal (SDG) specifically for SDG 6 on clean water and sanitation, which is essential in ensuring the availability and sustainable management of water and sanitation for all.

Keywords: Treated water; sewage; membrane treatment; vehicle wash water; water quality

INTRODUCTION

Sewage is essentially required to be treated properly as otherwise it can pollute water sources, damage natural habitats, and cause serious illnesses. Treated sewage usually is discharged back into the environment after following certain regulations. In Malaysia, sewage treatment plant effluent (STP) must comply with the standards of the Environmental Quality Act 1974 under the Environmental Quality Regulations 2009 to be discharged according to standards A and B, depending on the location of the discharge. STP effluent is used as a source of vehicle washing water if it has water quality that complies with certain standards and regulations, to avoid harm to the environment and human health. Evaluation of the raw water performance was measured by Sudiarti et al. (2024). It was found that parameters such infrastructure play a big role in ensuring sustainable water resource management, which can be applied in STP discharge management.

Nowadays, water recycling strategies have been implemented to ensure water sustainability, including the use of STP effluent for vehicle washing. The specifications for the use of STP effluent in vehicle washes usually include parameters such as suspended solids, chemical composition, color, oil, odor, and bacterial level to be used during the wash/wash phase. However, for the rinse phase, water with a low TDS content (soft water) is required to avoid damage to the vehicle's surface.

Vehicle washing water specifications typically involve parameters related to water quality and its impact on the environment. Considerations for the water quality parameters involved include pH, Total Suspended Solid (TSS), chemical oxygen demand (COD), biochemical oxygen demand (BOD), oil and grease, ammonia nitrogen, conductivity, Total Dissolved Solid (TDS), bacteria count, turbidity etc.

pH level is required to be maintained at a balance pH to avoid acidity or damage to the vehicle. The pH value is very important because the chemistry of water is greatly influenced by pH, or a measure of acidity or alkalinity. Meanwhile suspended solids must be ensured to be at low concentration. Next, chemical concentrations must be controlled to prevent damage to vehicles and the environment. This chemical composition can be determined in a variety of ways. TDS, hardness, and conductivity are parameters that can be used to indicate chemical composition indirectly. TDS monitors the concentration of water-soluble substances. Hard water is not good for washing vehicles because it can leave stains on the paint and spoil the quality of the wash. Mineral deposits in water can cause various problems for car wash equipment, the effectiveness of chemicals, as well as the result of the wash on the vehicle. Water used for professional car washing in developed countries should reportedly contain less than 50 mg/L TDS (ref). The following are the types of water according to the concentration of hardness in them.

1. Soft water contains up to 60 mg/L of calcium carbonate.
2. Medium-hard water contains 61 to 120 mg/L of calcium carbonate.
3. Hard water contains 121 to 180 mg/L of calcium carbonate.
4. Very hard water contains more than 180 mg/L of calcium carbonate.

On the other hand, monitoring the microbial content in water is very important for the cleanliness and safety of materials and consumers. Azmee & Mutalib (2022) through their study found that raw water samples before treatment at LRA around Seremban, Negeri Sembilan, recorded the highest amounts of coliform (7258.8 MPN/100 ml), E. coli (5198.7 MPN/100 ml), and enterococcus (997.5 MPN/100 ml). Meanwhile, for the treated water, all water samples were recorded at <1 MPN/100ml. An overseas study reported by Osualale & Okoh (2017) found that human enteric bacteria (coliform feces and E. coli) as well as viruses (rotavirus and enterovirus) were present in the effluent water of the final effluent of five STPs in the Eastern Region of South Africa. The human virus was identified from effluent samples by the absorption–lysis method and detected by a single real-time PCR test. Meanwhile, the detection of E. coli is made by placing a filter on the E. coli–coliform agar and incubating it at 37 °C for 24 hours. The content in STP effluent is quite high, up to hundreds/thousands of CFUs/100ml and is very worrying if exposed directly or indirectly to living organisms. To date, no regulations have been implemented to monitor the concentration of the virus in wastewater before it is discharged into water bodies (Osualale & Okoh 2017).

The use of water containing bacteria and viruses when washing vehicles is believed to affect the health of the user. This is because frequent contact between humans and fluids containing pathogenic microorganisms can provide opportunities for disease transmission. Pitol et al. (2020) have measured bacterial transfer (using *E. Coli* as a model) from liquid to skin, evaluated fluid retention on the skin after different contact activities (hand soaking, contact with wet cloths, and wet surface contact), and calculated fluid transfer after hand-to-mouth contact. His study found that if a person did hand soaking, encountered a wet cloth, or touched a surface containing water with a concentration of 103 E. coli/mL, 10 seconds after doing the activity, the

contamination on the hands would be 4.2, 4.3, and 5 *E. Coli*/cm², each for hand soaking, wet cloth touch, and wet surface touch. The relationship between the diffusion of bacteria/viruses in the skin to its concentration in a liquid solution is plotted in Figure 1.2. These results clearly show that contact with bacteria and viruses can cause them to permeate the skin, at much lower concentrations over a given period of exposure. The findings from this study focusing on *E. coli* diffusion may not be generalizable to other bacteria because different bacteria may have different rates of transfer. These risks in the event of contact with various bacteria, which may be present in STP effluent when used as vehicle wash water, cannot be ascertained.

The available data on the bacterial and viral content of STP effluent in Malaysia is also quite limited, making effluent consumers need to be cautious about its impact on public health. Additionally, a study by Gläser et al. (2005) showed that the presence of *E. coli* can cause keratinocytes on the skin to secrete the S100 protein, psoriasis, which selectively targets and kills *E. coli* by limiting its own presence in the skin microbiome. Additionally, when the skin is injured, likely from burn injury, after surgery, or due to eczema-like conditions associated with keratinocyte apoptosis, the presence of *E. coli* on the skin can lead to skin infections such as cellulitis, and in rare cases in type 1 necrotic soft tissue infections (NSTIs), in which the inner layers of the dermis, subcutaneous tissue, superficial fascia, or muscles become infected (Gallois et al. 2015). Skin infections caused by *E. coli* can be treated with antibiotics and certain *E. coli* bacteriophage cocktails (O'Sullivan et al. 2020), but bacterial infections can be avoided if water free of any bacteria is used in life, including washing vehicles. In conclusion, although *E. Coli* is capable of living in the body without causing any harm, it can also be an agent of death. Its presence has been shown to have an impact on skin health, as well as in other places on the body (Brockway 2020). Therefore, the use of non-bacterial water for car washing is essential to ensure the safety and health of consumers who encounter it. Previous study has been presented upon using different quality of water for overseas, but none has reported at the local used. The impact of using bacterial infected water must be confirmed as it may cause bad impact to the users.

Meanwhile, the use of water with a higher TDS concentration when the vehicle enters the initial wash phase can be practiced while the rinse phase uses water with a low TDS until the end of the wash (www.sobrite.com). STP effluent typically has a much higher TSS and TDS than fresh water from a water treatment plant (WTP) (Refer to Tables 2.1 and 2.2). The use of this water during the washing phase allows water to be saved compared to using water with low TDS in all washing/rinsing phases. Other water quality parameters such as the color of STP effluent,

which is usually slightly colored are acceptable for use, however the color must not be dark, dirty, greasy, or smelly, to allow it to be used in the washing/washing phase.

In addition, the use of hard water is not suitable for the washing phase with soap and other substances because hard water contains high ions such as calcium and magnesium. These ions can neutralize soaps, soap bubbles, and bubbles. If hard water is used with these softening/washing products, it can reduce the transfer of the chemical strength of the washing product, as well as reduce the efficiency of the softening/washing products used.

In developed countries, most car washes use reverse osmosis (RO) water as the water in the last rinse phase due to its low TDS content. In this way, the consumption of RO water can be reduced in quantity to be rinsed on the vehicle surface as other reusable water such as bacteria-free STP effluent can be used in the initial phase of washing. Examples of RO water quality obtained through a study by Praneeth et al. (2014). It was found that all water quality parameters are at very minimal or have no concentration, even though the quality of the wastewater to be treated is initially low. This indicates that the RO filtration method can improve the water quality to the best level and is suitable for use in the rinsing phase during vehicle washing activities. When the RO water meets the reusable water on the surface of the vehicle, it immediately absorbs the TDS contained in the hard water (from the initial wash/rinse phase). This measure was made to target the TDS left on the vehicle surface to 50 mg/L or less. If there is still soap on the surface of the vehicle, the RO water will absorb the ions in the soap and make the TDS concentration of the contact water exceed 50 mg/L. Therefore, more thorough washing/ rinsing should be done to ensure that the surface of the vehicle can be properly maintained after washing.

Theoretically, the water treatment method using pressurized filtration membrane technology can remove various materials based on the principle of the size of the membrane pore diameter as well as the pressure applied during the filtration. For example, UF membranes can reject all bacteria and viruses from passing through them if the pore diameter of the membrane used is around 100 Å. RO membranes, on the other hand, reject all types of bacteria, viruses and proteins, and allow only simple salts and sugars along with water to pass through, depending on the pore size as well. If a 'tight' RO is used, only monovalent water and salt can pass through it making it the main alternative method for obtaining drinking water/ demineralized water used for certain boilers and processes in the plant. There are 5 types of membrane modules that are commonly used in industry namely plate-and-frame, tubular, hollow fiber, spiral wound and capillary module. This module is selected according to the type of membrane and solute of the solution to be removed, intended to support the membrane

used. Spiral wound module is the most used as it is easy to assemble/ maintain with high flux.

Therefore, this work is aimed to identify the physical implementation of using polished water from STP through effluent water quality laboratory experiments. The latest information related to effluent, treated effluent, water reuse at the targeted site in terms of quality/quantity is to be investigated. Finally appropriate treatment processes are to be proposed to meet vehicle washing water standards. From this work, it is expected that treated sewage using membrane technology can be used to produce clean water of vehicle wash water standards. So far there is no study presented on the required water quality for this application. Literature review as well as technical study are conducted and presented herein to support the findings. Therefore this study has analysed the water at various qaulity parameters and the right treatment method is proposed to make sure safe and clean water is produced, and used for car wash application. A guideline can be proposed from this study, which to be used for car wash water application from treated sewage.

MATERIAL AND METHODS

WATER SAMPLING AND ANALYSIS

Sewage from certain population equivalent (PE) is compulsory to be treated in STP in Malaysia prior to effluent discharge. This effluent is expected to be further treated to be reused for various purposes including vehicle wash water. In this study, STP in Kuala Lumpur was chosen as the study area because this dedicated STP possesses polishing water facilities using membrane technology. Sewage was initially treated using a biological treatment system utilizing anaerobic, anoxic and oxyctic reactor system (A2O) to treat sewage from the surrounding area of 1.8 million P.E. from 8 catchment areas. In addition, it has a system that reuses effluent by making an advanced treatment of effluent of 1% of the total capacity, which is equivalent to 2 MLD (around 800 m^3/day). The effluent for reuse is treated with 3 main filtration methods, namely multimedia filtration, ultra filtration (UF) and reverse osmosis filtration (RO), as well as disinfection using a UV system, so that it can be used for specific purposes. The flow chart for the overall work is presented in Figure 1.

Water quality results recorded for a period of 1 year from November 2022 to October 2023 at the STP show that the BOD, COD, total suspended solid (TSS) and ammonia in the effluent meet the standards of the Environmental Quality (Sewage) Regulations 2009 (DOE). The values of BOD (2.2 – 4 mg/L), COD (17 – 25 mg/L), SS (2 – 5.6 mg/L) and ammonia (2.2 – 9 mg/L) are relatively high compared to the values set for treated water from drinking water standards by Ministry of Health (MOH) Malaysia.
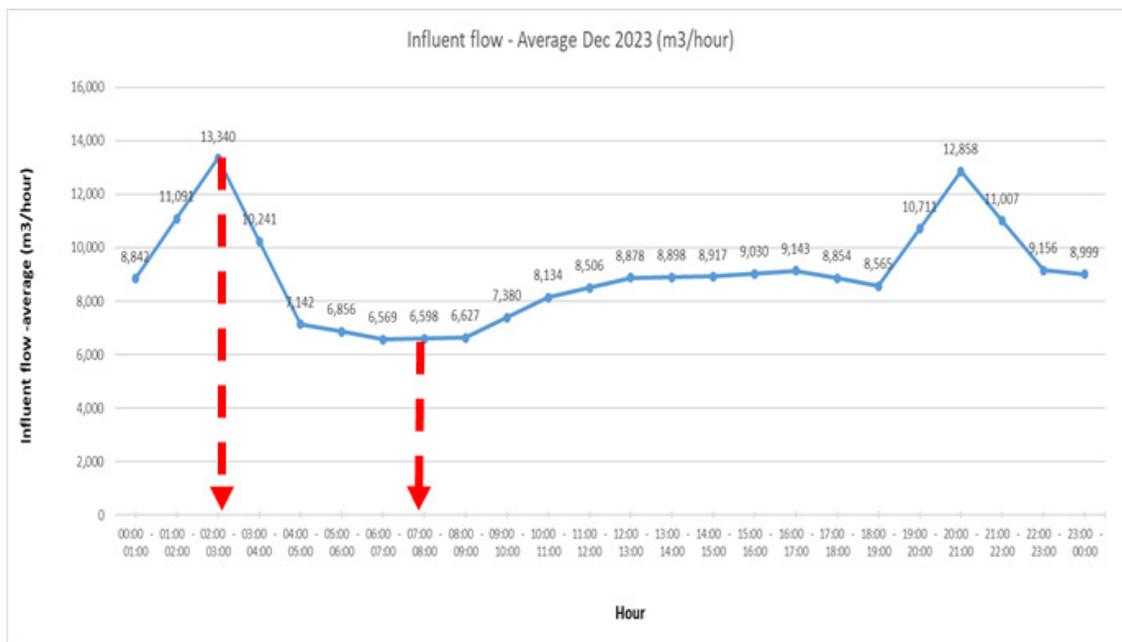

FIGURE 1. Average inflation flow rate measured throughout December 2023 and observed on an hourly basis

WATER QUALITY

There are 12 quality parameters of treated effluent water that have been identified as important to be used to determine the level of quality of treated water that is suitable for use as vehicle wash water. These parameters are stated together with the permissible limits according to 2 standards, namely Class I National Water Quality Standard (NWQS) and Drinking Water Quality Standards issued by the Ministry of Health Malaysia, as presented in Table 1. In addition, the method of determining the parameters as well as the standard method used are also specified.

SAMPLING METHOD

The sampling method that has been done is as stated in Table 2. A total of 3 L of water samples were taken and placed in three (3) bottles of 1 L volume separately, and later tested for all 12 parameters stated. There were two (2) colours of bottles used, namely white and black, where black bottles were used to preserve samples for biological analysis (helping to inhibit the activity of samples in the absence of light). Samples were also kept cold at 4°C and immediately brought to the analysis location and stored at 4°C before the analysis was carried out.

METHODS OF DETERMINING WATER QUALITY PARAMETERS

Details for each parameter determination method have been shown in Table 1. The information in this table is based on the analysis that has been made of the samples that have been taken at the dedicated STP. A total of eight (8) water samples that were taken according to the sampling table as presented in Table 1 were analyzed for the twelve (12) water quality parameters that had been identified. All analyses for the twelve (12) parameters tested are in accordance with specific APHA standards and are set out in Table 1.

TABLE 1. Water quality parameters for use as vehicle wash water

No	Parameter	Unit	Class I NWQS	Drinking Water Quality (MOH)	APHA Standard	Parameter Determination Method
1	pH	-	6.5 – 8.5	6.5 – 9.0	APHA- 4500 H+B	pH meter
2	Conductivity	uS/cm	1000	-	APHA 2510 B	Conductivity Meter
3	Turbidity	NTU	5	5	APHA2130 B	Turbidimeter
4	Hardness	mg/L	-	500	APHA 2340B	Spectrophotometer
5	TSS	mg/L	25	-	APHA 2540C	Filtration
6	TDS	mg/L	500	1000	APHA 2540C	Spectrophotometer
7	Ammonia nitrogen (NH_3-N)	mg/L	0.1	1.5	APHA 4500-NH3 B&F	Spectrophotometer
8	Oil & Grease (O&G)	mg/L	-	-	APHA 5520B	Extraction
9	COD	mg/L	10	-	APHA 5220C	Spectrophotometer
10	BOD	mg/L	1	-	APHA 5210B	Incubation
11	*E. Coli*	Count/100ml	10	0	APHA 9221E	Microbial Test
12	Total Coliform	Count/100ml	100	0	APHA 9221E	Microbial Test

TABLE 2. Sampling method of tested treated effluent water quality parameters

No	Analysis	Storage Container	Preservation	Storage Period
1	pH	Plastic	4°C	Immediate
2	Conductivity	Plastic	4°C	28 days
3	Turbidity	Plastic	4°C	48 hours
4	Hardness	Plastic	4°C	6 months
5	TSS	Plastic	4°C	7 days
6	TDS	Plastic	4°C	7 days
7	Oil & Grease	Glass	4°C	28 days
8	NH_3-N	Plastic	4°C	28 days
9	COD	Plastic	4°C	24 days
10	BOD	Dark Plastic	4°C	24 days
11	*E. Coli*	Dark Plastic	4°C	48 days
12	Total Coliform	Dark Plastic	4°C	48 days

RESULTS AND DISCUSSION

SAMPLING EXERCISE AND RESULTS

The sampling frequency was determined in accordance with the trend of the average daily effluent production rate in 2022 and 2023 for each month. This data was shared by STP operator for the purpose of determining the appropriate sampling time. The data provided are as presented in Table 3. The average effluent withdrawal rate in December 2023 applies because in December 2023, the average inflation flow rate was made every hour of the day. This inflation flow rate has been found to have a certain trend of hourly fluctuations. In addition, the average water reuse is also proportional to the average effluent removed per day as shown in Table 3. In December 2023, a total of 158,758 m³/day of water was removed while an average of 1,705 m³/day of water was reprocessed. This is the highest rate obtained for this 2-year period.

Furthermore, the average daily inflation flow rate throughout December 2023 has been measured and presented in Table 4. This table provides the average inflation flow rate during December 2023 for each day, as well as the average values of the BOD, COD, SS, NH_3-N and O&G parameters that have been obtained from the analysis conducted on the inflation. Table 4 shows that the peak time for the average inflation flow rate is at 2.00 – 3.00 am which is 13,340 m³/day. This value means that consumer activity at that time is the highest in a day, resulting in the highest amount of effluent water reaching Pantai 2 STP. Meanwhile, the average value of the lowest trend, which can also be categorised as non-peak hours, was observed at 6.00 – 8.00 am with a value almost half lower than the value during peak hours at 2 – 3 am. This data from the same source in Malaysia has never been reported in open literature before. However, similar trend of the influent parameters entering the ETP was presented in (Metcalf & Eddy 2013).

Figure 1 further shows the value of this flow rate plotted in the form of a graph so that it is easier to see the insights at peak hours (2 – 3 am) and non-peak times (6 – 8 am). In addition, the water quality value of the sewage waste influent also did not meet the Wastewater Treatment Plant Environmental Quality Standards 2009 (EQ STP regulation 2009) for all 5 parameters measured namely BOD, COD, SS, NH_3-N and O&G. For example, it must be treated before being released, or even reused. For the dedicated STP, the water quality parameters as shown in Table 4 must meet Standard B (EQ STP 2009) but the plant puts a much lower value of Standard A to be met to maintain the quality of the water discharged. According to the plant, a treatment time of 10 hours is required to treat the effluent water, before it is clean and can be discharged to the point of discharge after meeting the EQ STP 2009 standards. Therefore, the ideal time for effluent sampling to be done at the STP is after 10 hours after it is entered the plant. This sampling information can be seen in Figure 2. Based on this information, it has been determined that samples for peak hours are taken at 12.30 pm while samples for non-peak hours are taken at 5.00 pm, after considering the additional 10 hours required for the water treatment.

TABLE 3. Average effluent production per day (m³/day) per month throughout 2022-2023

Year	Month	Average Effluent Production Per Day (m³/day)	Average Reuse Water Production Per day (m³/d)
2022	January	133,178	1,282.32
	February	132,578	723.57
	March	146,513	744.05
	April	142,169	861.67
	May	138,435	943.42
	June	143,570	1,288.92
	July	139,025	1,409.34
	August	155,081	1,166.76
	September	140,154	981.34
	October	145,413	1,071.00
	November	152,968	1,034.93
	December	156,625	1,049.71
2023	January	144,583	1,173.29
	February	149,442	1,177.43
	March	146,517	1,287.23
	April	152,257	1,289.27
	May	152,247	1,235.61
	June	145,359	1,317.53
	July	149,606	1,380.47
	August	147,688	1,304.61
	September	148,175	1,670.37
	October	155,850	1,764.48
	November	155,393	1,527.40
	December	158,798	1,704.94

TABLE 4. Average influent flow rate measured throughout December 2023 identified on every hour of the day and the effluent water quality that treated against the STP standards (2009)

Hour	Influent flow - Average Dec 2023 (m³/hour)	BOD (mg/l)	COD (mg/l)	SS (mg/l)	NH3-N (mg/l)	O&G (mg/l)
00:00 - 01:00	8,842					
01:00 - 02:00	11,091					
02:00 - 03:00	13,340					
03:00 - 04:00	10,241					
04:00 - 05:00	7,142					
05:00 - 06:00	6,856					
06:00 - 07:00	6,569					
07:00 - 08:00	6,598					
08:00 - 09:00	6,627					
09:00 - 10:00	7,380	60	130	61	15	20
10:00 - 11:00	8,134					
11:00 - 12:00	8,506					
12:00 - 13:00	8,878					
13:00 - 14:00	8,898					
14:00 - 15:00	8,917					
15:00 - 16:00	9,030					
16:00 - 17:00	9,143					

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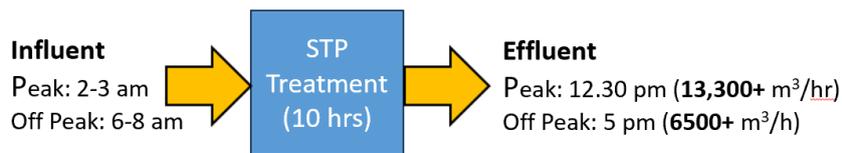|						
17:00 - 18:00	8,854					
18:00 - 19:00	8,565					
19:00 - 20:00	10,711					
20:00 - 21:00	12,858					
21:00 - 22:00	11,007					
22:00 - 23:00	9,156					
23:00 - 00:00	8,999					
EQ Sewage (A)	Nil	20	120	50	10	5
EQ Sewage (B)	Nil	50	200	100	20	10

FIGURE 2. Determination of sampling time based on the rate of effluent water during peak hours and not off-peak peaks throughout December 2023

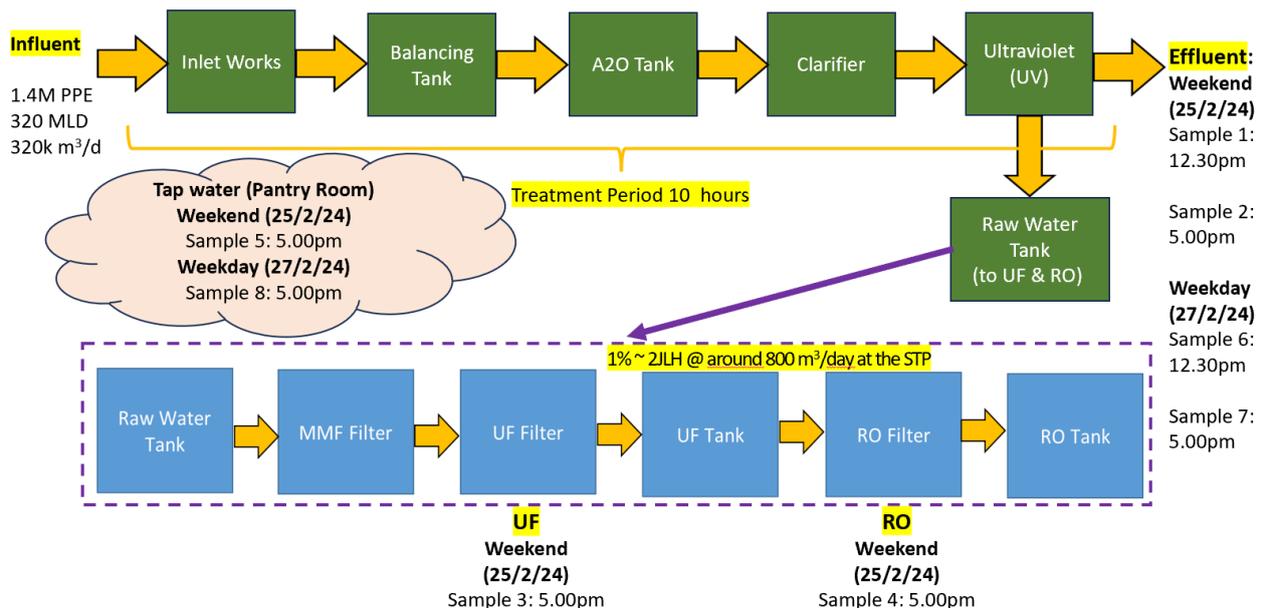

FIGURE 3. Location and sampling and time carried out at the dedicated STP

TABLE 5. Information related to sampling conducted for a specific location

Date/ Time	No.	Sample Name	Time (pm)	Location
Weekend 25 Feb. 2024	1	Effluent	12.30	Effluent Well
	2	Effluent	5.00	Effluent Well
	3	UF	5.00	UF Inlet Flow
	4	RO	5.00	Sampling Valves (15 & 16)
	5	Tap Water	5.00	Pantry Room
Weekday 27 Feb. 2024	6	Effluent	12.30	Effluent Well
	7	Effluent	5.00	Effluent Well
	8	Tap Water	5.00	Pantry Room

Subsequently, several other samples, i.e. other than effluent after treatment during peak and non-peak treatment were also identified for comparative analysis in this study. Referring to Figure 3, the effluent produced at the dedicated STP has undergone a biological and conventional treatment process using an A2O bioreactor. Therefore, effluent samples at peak and non-peak hours were taken for the purpose of quality analysis. A comparison of samples taken during weekdays and weekends was also made to see how they compare. This is because the needs and treatment process may differ slightly at different times.

In addition, there is 2% effluent water taken and treated through an advanced treatment process using ultrafiltration membrane (UF) and reverse osmosis (RO) methods aimed at reusing the water for specific purposes. Therefore, samples of these two waters were also taken to compare their quality. Lastly, to ensure that the treated water from the dedicated STP is of reliable quality to be reused as vehicle wash water, samples of tap water supplied by the local WTP Operator to the STP were also taken at 2 different times for comparison. This is because tap water must follow the drinking water standards issued by the MOH, and the quality is suitable for the water that is usually used for vehicle washes at vehicle wash centers in Malaysia. Meanwhile the quality of wash water may drop significantly as suggested by Hashim & Zayani (2016). They may include phosphate, oil and grease, alkalinity, TSS and others. Therefore, if the treated water, whether effluent, UF, or RO water, at the STP has the same or better quality than tap water taken directly from the direct water supply point at this STP, it is believed that the use of treated water from this STP as vehicle wash water will be more reliable and safer. This will also ensure that the vehicle is protected from dirt and harmful ionic attack as well as better effluent quality compared to using the low-quality water (Sobrite). Table 5 shows a summary of the sample name, location and date the sample was taken as well as relevant information about the sampling that has been taken. A total of eight (8) samples were taken with sampling information as stated in the table. Le & Nguyen (2024) has suggested a method known as TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) in order to rank water quality at each location, identifying areas that require priority in mitigation and treatment efforts. However, in this study, the method has not been applied since a minimum sampling point was identified.

WATER QUALITY ANALYSIS RESULTS

Table 6 shows the water quality parameters that need to be measured according to drinking water standards as well as NWQS. For each of these parameters, the method of determining the parameters stated according to the standard testing method stipulated in Table 1 must be the same as the standard testing method used by the STP so that the observed values are in almost the same range. Details of the methods used are also stated in this table for further explanation. The results of the water quality test measured for four (4) samples of treated effluent water as well as the prescribed sampling time are presented in Table 7. Based on Table 7, almost all treated water from the dedicated STP is good and meets the environmental quality sewage regulations 2009 for Standards A and B. However, the readings for this parameter are much lower when compared to drinking water standards and NWQS. This means that treated effluent water that is normally discharged to the point of discharge and meets STP standards, needs to be treated through an advanced treatment process using UF and RO treatment systems, as what has been done at the STP, for it to be reused in the plant.

Furthermore, the water quality analysis of UF and RO water taken to compare with drinking water supplied by Air Selangor, was carried out and presented in Table 8. It can be seen that UF water is not suitable for use yet without further treatment because its quality is still quite far from the standard value – tap water samples. This is likely because the UF treatment system is still insufficient to achieve the quality of drinking water. This is supported by the results of the analysis of biological tests where bacteria were still detected in the effluent and UF treated water, which did not undergo the RO treatment process. Bacteria presence in water may cause various implications especially when contacting skin, as reported by (Glaser 2005; Gallois,2015; Osualale 2017; Pitol, 2020). However, only RO water was found to have a much better water quality than any treated effluent water, including the tap water supplied by and sampled and analyzed. For all the water treatments used, the UV treatment method is not used in any of these treatment processes so that the bacteria content in the effluent water and UF water still has tens to hundreds of counts of bacteria (count/100 ml) in it. This was in contrast with the RO samples as well as tap water in which no bacteria has been detected. Therefore, the quality of RO water can be concluded to be very good or equivalent to the tap water that was taken at that time. However, UF water has a slightly better quality compared to effluent water such as TSS, BOD and COD content when compared to the data in Table 7. Nevertheless, its biological content is still found to be quite high and exceeds the standards set by NWQS and MOH.

Table 7 and 8 show the parameters that are still not complied (with red font) with the MOH and NWQS standards, even after considering the 12 parameters investigated in this study. For effluent water, there are seven (7) out of twelve (12) parameters that were still not complied with while UF has only four (4) out of twelve (12) parameters that were not complied with. For UF water, possession of four (4) uncompiled parameters are still quite large compared to the total 12 parameters, thus the UF water will not be accepted as a source of vehicle wash water. The UF water needs to be treated using tighter membrane pore structures. Lastly, RO water and tap water are of the best quality and the same makes them the best candidates for use in vehicle washing facilities.

Similar work on optimizing treatment process for wastewater has been reported in (Santis et al. 2024). This process utilized photocatalysis, which is opposite from the membrane processes. However the aim is similar, which to contribute to environmental protection effort.

UF AND RO WATER QUALITY AS VEHICLE WASH WATER

The use of water with low TDS when washing and rinsing a vehicle is essential to take care of the vehicle's surface. Other water quality parameters such as its color must not be dark, dirty, oily, or smelly, to allow it to be used in the washing and washing phases. In addition, the use of hard water is not suitable for the washing phase with soap and other substances because hard water contains high ions such as calcium and magnesium. These ions can neutralize soaps, soap bubbles, and bubbles. If hard water is used with these softening/ washing products, it can reduce the transfer of the chemical strength of the washing product, as well as reduce the efficiency of the softening/washing products used. Therefore, these hardness parameters, TDS, conductivity are measured and compared between UF water, RO and tap water and the results are presented in Figure 4.

TABLE 6. Water Quality Parameters Against Different Standards & Testing Methods

No.	Parameter	Unit	Class I INWQS	Drinking Water Quality (MOH)	Method in This Study	Method by STP Operator	Detail Method in This Study
1	pH	-	6.5-8.5	6.5-9.0	APHA-4500 H+B	APHA 4500 H+B	HACH HQ11d
2	Conductivity	uS/cm	1000	-	APHA 2510 B	-	HACH HQ11d
3	Turbidity	NTU	5	5	APHA 2130 B	EUTECH TN-100	HACH 2100N
4	Biological Oxygen Demand (BOD)	mg/L	1	-	APHA 5210 B	APHA 5210 B & APHA 4500 O G	BOD Incubation Daihan
5	Chemical Oxygen Demand (COD)	mg/L	10		APHA 5220C	APHA 5220 B	HACH DR 3900
6	Ammonia-N	mg/L	0.1	0.5	APHA 4500-NH3 B&F	APHA 4500-NH3 D	HACH DR 3900
7	Total Suspended Solids (TSS)	mg/L	25	-	APHA 2540D	APHA 2540 D	vacuum pump set and 934-AH Whatman filter paper
8	Total Dissoved Solids (TDS)	mg/L	500	1000	APHA 2540C	EUTECH CON 2700 (Test probe)	HACH DR 3900
9	Total Hardness as CaCO3	mg/L	-	500	APHA 2340B		HACH DR 3900
10	Oil and Grease	mg/L	-	-	APHA 5520B	APHA 5520 D	Rotary evaporator
11	E-Coli	Count/100ml	100	0	APHA 9221E	-	HACH Colilert Set
12	Total Coliform	Count/100ml	100	0	APHA 9221E	-	HACH Colilert Set

TABLE 7. Results of the dedicated STP effluent analysis and comparison with relevant standard values

No	Parameter	Unit	1-Effluent 25/2;12.30	2-Effluent 25/2;5.00	6-Effluent 27/2;12.30	7-Effluent 27/2;5.00	Class I NWQS	Drinking Water Quality MOH	Sewage Reg. 2009(A)
1	pH	-	6.95	6.97	7.01	6.98	6.5 – 8.5	6.5 – 9.0	6.0 – 9.0
2	Conductivity	uS/cm	260	255	286	296	1000	-	-
3	Turbidity	NTU	5.03	7.50	3.25	4.66	5	5	-
4	Biological Oxygen Demand (BOD)	mg/L	9	5	10	17	1	<5 (WHO)	20
5	Chemical Oxygen Demand (COD)	mg/L	23	51	44	35	10	-	120
6	Ammonia-N	mg/L	14.4	13.3	14.3	14.2	0.1	1.5	10 (20 Std B)
7	Total Suspended Solids (TSS)	mg/L	18	10	19	25	25	-	50
8	Total Dissolved Solids (TDS)	mg/L	175	175	195	190	500	1000	-
9	Total Hardness as CaCO3	mg/L	43.8	45.4	47.1	47.2	-	500	-
10	Oil and Grease (O&G)	mg/L	<1	<1	<1	<1	-	-	20
11	E-Coli	Count/ 100ml	170	110	350	220	10	0	-
12	Total Coliform	Count/ 100ml	330	400	350	220	100	0	-

TABLE 8. Results of water analysis using membrane system compared to tap water

No	Parameter	Unit	3-UF water 25/2;5.00	4-RO water 25/2;5.00	5-Tap water 25/2;5.00	8-Tap water 27/2;5.00	Class I NWQS	Drinking Water Quality MOH	Sewage Reg. 2009(A)
1	pH	-	6.92	7.26	6.93	7.22	6.5 – 8.5	6.5 – 9.0	6.0 – 9.0
2	Conductivity	uS/cm	255	15.81	86.1	86.6	1000	-	-
3	Turbidity	NTU	0.33	0.15	0.69	1.70	5	5	-
4	Biological Oxygen Demand (BOD)	mg/L	3	2	2	2	1	<5 (WHO)	20
5	Chemical Oxygen Demand (COD)	mg/L	9	5	5	6	10	-	120
6	Ammonia-N	mg/L	13.1	0.01	0	0	0.1	1.5	10 (20 Std B)
7	Total Suspended Solids (TSS)	mg/L	3	5	6	2	25	-	50

... cont.

8	Total Dissolved Solids (TDS)	mg/L	175	7	60	190	500	1000	-
9	Total Hardness as CaCO3	mg/L	44.1	<0.1	36.3	32.2	-	500	-
10	Oil and Grease (O&G)	mg/L	<1	0	0	0	-	-	20
11	E-Coli	Count/ 100ml	14	N/D	N/D	N/D	10	0	-
12	Total Coliform	Count/ 100ml	70	N/D	N/D	N/D	100	0	-
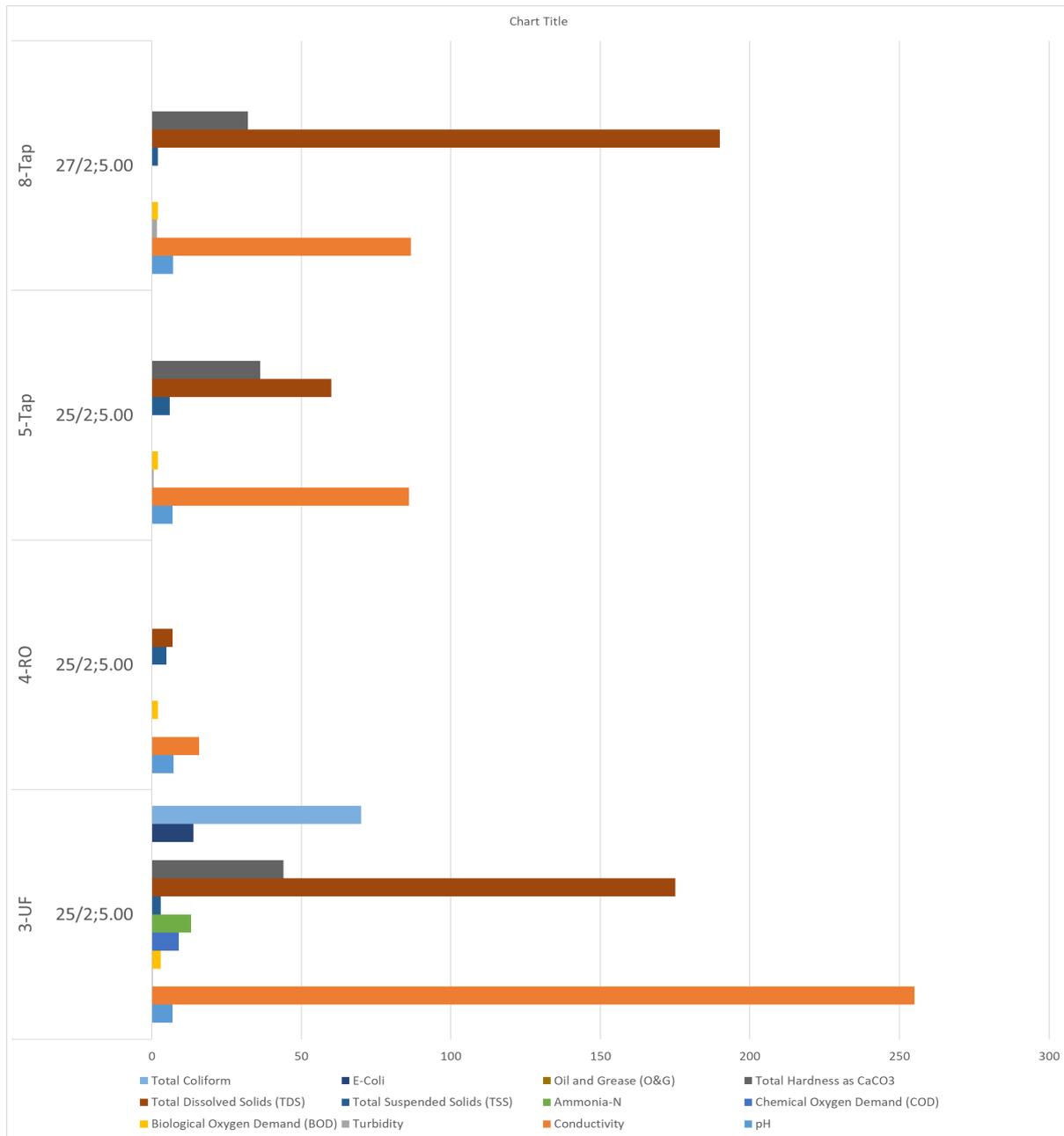
FIGURE 4. Comparison of UF, RO and tap water qualities measured at 2 different times

Based on this result in Figure 4, RO water has the best quality of all measured parameters, followed by tap water and UF water. The conductivity value was found to be quite high for UF, but still low compared to the NWQS standard value which is below 1000 mg/L. The highest TDS value is for UF water with more than 150 mg/L. This value is three times greater than what is suggested from the literature for vehicle washes, which are below 50 mg/L (www.sobrite.com). In addition, the bacterial content in UF water was also found to be quite high, exceeding 70 count/100ml. This amount is not good at all because the bacteria in the water can affect the health of the water users. This is because frequent contact between humans and fluids containing pathogenic microorganisms can provide opportunities for disease transmission. This also rejects UF water as a suitable water candidate for use as water for vehicle washing. Therefore, only RO water is seen as the best candidate to be used for this purpose. Further treatment using a UV system is also suggested as there are still possible traces of bacteria in RO water/ tap water samples for a long storage period. An in-situ UV system installed in a pipe/ storage tank may be a good alternative to use as well as save on installation and repair costs. The setting of the UV energy source open and close control system can also save energy as well as prolong the life span of the UV bulbs used.

CONCLUSION

Based on a comprehensive literature study conducted and observations made at the dedicated STP, the STP's effluent can be used as a source of vehicle wash water if it goes through a certain advanced treatment process. The first advanced treatment recommendation is to use a UF filtration system followed by the second recommendation to use RO treated water to treat the water to meet vehicle wash water requirements. The addition of disinfection process is needed to ensure that there are no harmful bacteria present in this treated water, to minimize the water user's contact with it.

Based on water quality analysis, it can be concluded that the effluent water and UF water still do not meet the water standards for vehicle washing water. The effluent water needs to be treated to be used as the water source. It was also found that RO water has the best quality comparable to tap water and has become the best candidate for the vehicle wash water source. RO membrane treatment method is the most effective technique to be used for obtaining good water quality following the MOH and NWQS standards. Addition of UV treatment system for antibacterial treatment is essential in ensuring that no bacteria/ virus can be penetrated in the treated water.

This study has confirmed that the guidelines referred can become the basis of potable water quality suitable for car wash application. SDG 6 on clean water and sanitation can be contributed from the study to ensure availability and sustainable management of water and sanitation for specific applications. Further study of the commercial and economic aspects of its utilization can be done in the next scope.

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DECLARATION OF COMPETING INTEREST

None.

REFERENCES

Azmee, N. & Mutalib, N.A.A. 2022. Assessment of coliform, escherichia coli, and enterococci in raw and treated water in negeri sembilan, and factors associated with the decontamination procedure. *Malaysian Journal of Fundamental and Applied Sciences* 18: 714-725.

Barbara Brockway. 2020. Introducing Escherichia coli (E. coli) part 1, The Secret Life of Skin, https://thesecretlifeofskin.com/2020/11/10/introducing-e-coli/

DOE, https://www.doe.gov.my/wp-content/uploads/2023/01/Environmental_Quality_Sewage_Regulations_2009_-_P.U.A_432-2009.pdf (accessed 5th June 2024)

Gallois, C., Hauw-Berlemont, C., Richaud, C., Bonacorsi, S., Diehl, J.L., Mainardi, J.L. 2015. Fatal necrotizing fasciitis due to necrotic toxin-producing Escherichia coli strain. *New Microbes New Infect.* 8: 109-112.

Gläser, R., Harder, J., Lange, H. et al. 2005. Antimicrobial psoriasin (S100A7) protects human skin from Escherichia coli infection. *Natural Immunology* 6: 57–64.

Hashim, N.H. & Zayadi, N. 2016. Pollutants characterization of car wash wastewater. *The 3rd International Conference on Civil and Environmental Engineering for Sustainability (IConCEES 2015)* 47: 1-6.

Le, K.D. & Nguyen, G.T. 2024. Applying harmony degree equation and TOPSIS combined with entropy weights in surface water classification. *Civil Engineering Journal* 10(4): 1-15.

Metcalf & Eddy. 2013. *Wastewater Engineering: Treatment and Resource Recovery*. 5th edition. McGraw-Hill Education.

MOH,https://www.moh.gov.my/index.php/dl/64584e6c636c38784d54677655476c68643246705957356533 3566862476c306156394261584a6654576c7564573 0756347526d (accessed 5th June 2024)

O'Sullivan, J.N., Rea, M.C., Hill, C. & Ross, P.R. 2020. Protecting the outside: biological tools to manipulate the skin microbiota. *FEMS Microbiology Ecology* 96.

Osualale, O. & Okoh, A. 2017. Human enteric bacteria and viruses in five wastewater treatment plants in the Eastern Cape, South Africa. *Journal of Infection and Public Health* 10: 541–547.

Pitol, A.K., Kohn, T. & Julian, T.R. 2020. Retention of E. coli and water on the skin after liquid contact. *PLoS ONE* 15(9): e0238998.

Praneeth, K. Bhargava, S.K. Tardio, J. & Sridhar, S. 2014. Water recovery from domestic kitchen effluent through membrane separation processes, Chemeca 2014: Processing excellence; Powering our future.

Qian, S., Hou, R., Yuan, R. Zhou, B. Chen, Z. & Chen, H. 2022. Removal of escherichia coli from domestic sewage using biological sand filters: Reduction effect and microbial community analysis. *Environmental Research* 209.

Rashid, A.I.M, Rohani, R., Jaafar, O. & Muhammad, N.S. 2021. Chlorine decay and formation of THM in Malaysia's water distribution system. *Environment Protection Engineering* 47(4): 19-41.

Santis, A., Arbeláez, O., Cardenas, L.A., Castellanos, J. & Velasquez, P. 2024. Optimizing Cr(VI) reduction in plastic chromium plating wastewater: particle size, irradiation, titanium dose. *Emerging Science Journal* 8(1): 1-12.

SoBrite Water Treatment Solutions 2024, www.sobrite. com (accessed on 5th January 2024).

Sudiarti, S.U, Andawayanti, U., Limantara, L.M., & Siswoyo, H. 2024. Performance index model of raw water infrastructure. *Civil Engineering Journal* 10(6): 1-10.