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Effectiveness of Centralized Wastewater Treatment Plant in Removing Emerging Contaminants: A Case Study at Kuching, Malaysia

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Abstract

Before the construction of the Kuching Centralized Wastewater Treatment System Package 1 (KCWTSP1), partially treated blackwater and greywater were discharged directly into natural waterways. The accumulated wastewater had polluted Sarawak river, which is regulated and cannot discharge freely into the South China Sea. The polluted Sarawak river has endangered human health, river water quality, and aquatic ecosystems. Hence, the KCWTSP1 commissioned in 2015 serves the purpose of removing pollutants from wastewater before it is discharged into natural waterways. However, the effectiveness of KCWTPP1 is unknown. This paper is aimed to discuss and review the effectiveness of KCWTPP1 in treating wastewater since its inception in 2015. From 2017 to 2020, KCWTPP1 has treated an average of 4,200,000 m^3 of wastewater per year. Generally, most of the discharge effluent met Environmental Quality Act (1974) Standard A criteria, except for the oil and grease parameter. Initially, the plant could not treat suspended solids and total phosphorus, but this was greatly improved in subsequent years. Therefore, some improvements are required to treat oil and grease parameters effectively and efficiently to ensure that only Standard A effluent is discharged into the Sarawak River in the future.

Keywords

Kuching Centralized Wastewater Treatment Plant Package 1, Primary

Treatment, Secondary Treatment, Tertiary Treatment, Effluent

1. Introduction

Water is essential for the survival of all plants and animals. Water covers approximately 71% of the Earth's surface, but only 2.5% of the Earth's water is freshwater. Nowadays, rapid urbanization and industrialization have resulted in rapid population growth, increasing water demand and releasing massive amounts of wastewater into natural waterways. Urbanization and industrialization have resulted in significant economic activity, the maintenance of numerous livelihoods, particularly farmers, and significant changes in the water quality of natural bodies of water [1]. However, as a result of industrialization and urbanization, water is becoming more polluted, and the risk of polluted water consumption and sanitation problems is increasing daily in most developing countries. Water scarcity has a significant negative impact on global economic development, human livelihoods, and environmental quality. As a result, protecting water from pollution or developing cost-effective remedial methods has become a critical need in today's environment.

Worldwide, it is estimated that approximately 1.1 billion people drink contaminated water. According to the World Bank, water-related diseases account for 21% of communicable diseases, with India having the highest rate [2]. In 2004, diarrhea alone is estimated to have killed over 535,000 Indians. The most common microbial populations found in wastewater treatment systems are bacteria, protozoa, viruses, fungi, algae, and helminths, which have significantly increased the risk of disease transmission.

Pollutants and contaminants commonly found in wastewater include colloidal material (suspended aluminosilicate), organic matter, pathogenic agents originating from both domestic sewage and improperly treated animal waste, pesticides and fertilizers used on crops, and active pharmaceutical compounds (PhCAs) [3] [4] [5]. Nitrogen and phosphorus are the two most common chemical pollutants in wastewater, and they are also the primary nutrients that cause eutrophication. Traditional treatment methods for removing colloids, organic matter, fertilizers, and pathogenic agents from wastewater include phase separation, filtration/adsorption, anaerobiosis, and mixed microbiological systems. However, these methods cannot completely remove dissolved micropollutants such as pesticides, hormones, and PhCAs. Furthermore, the processes of decantation, filtration, and disinfection are used in sequence to treat the pre-treated wastewater [6].

Various conventional wastewater treatment methods have existed since antiquity [7] [8] [9], but some are prohibitively expensive and inefficient. High-income countries treat roughly 70% of municipal and industrial wastewater on average. This proportion falls to 38% in upper-middle-income countries and 28% in lower-middle-income countries [10]. Only 8% of wastewater in low-income countries was treated [11]. These findings support the widely held belief that more than 80% of all wastewater is discharged untreated globally. In high-income countries, the motivation for advanced wastewater treatment is either to maintain environmental quality or to provide an alternative water source when dealing with water scarcity. However, due to a lack of infrastructure, technical and institutional capacity, and funding, the release of untreated wastewater remains common practice, particularly in developing countries.

Apart from wastewater treatment plants, several methods for improving river water quality have been identified, including reducing pollution, eliminating dumping and minimizing the release of hazardous chemicals and materials, halving the proportion of untreated wastewater, and significantly increasing recycling and safe reuse globally. In today's world, wastewater treatment is critical for protecting the river ecosystem and ensuring sustainable living. The efforts required to achieve the goal of sustainable living will place a more significant financial burden on low- and lower-middle-income countries, putting them at a competitive disadvantage compared to high- and upper-middle-income countries [12].

Wastewater management is currently in crisis in developing countries worldwide, including Kuching, Sarawak, the largest city in Borneo Island. Kuching's current population is around 600,000 people, and it will continue to grow due to rising population density [13] [14]. Partially treated septic tank wastewater and greywater from kitchens, bathrooms, and laundry areas are discharged directly into natural waterways without adequate treatment, posing severe risks to human health, economic productivity, the quality of ambient freshwater resources, and ecosystems. The Sarawak River, on the other hand, operates under a controlled regime in which a barrage and shiplock control the inflow and outflow of water from the river basin at the river basin outlet. Since Sarawak River water cannot freely discharge into the South China Sea, all pollutants from partially treated blackwater and untreated greywater will accumulate and become a significant source of pollution in the Sarawak River [15]. The immediate effects of the polluted Sarawak river basin, such as aquatic ecosystem degradation and waterborne illness caused by contaminated freshwater supplies, have far-reaching consequences for community well-being and livelihoods.

According to a study conducted by the Malaysian Department of Environment (DOE), the Sarawak River's water quality is deteriorating and has been categorized as Class IIB/III. River pollution in some tributaries is severe and classified as IV/V, particularly in Kuching city areas [16] [17]. As a result, the Kuching Sustainable Wastewater Management System (KSWMS) was established to remove pollutants from the sewage to meet Department of Environment Standard A effluent discharge, which is deemed clean and safe for water-based activities, before discharging into natural waterways. This will reduce environmental consequences and is part of the government's ongoing efforts to improve living conditions in Kuching. This paper will discuss and review the effectiveness of

Kuching Centralized Wastewater Treatment System Package 1 (KCWTSP1), which has been in operation since 2015.

2. Study Area

The Kuching Centralized Wastewater Treatment System has been chosen as the study project, and it is currently divided into two packages: the KCWTSP1 under the Ninth Malaysia Plan and the Kuching Centralized Wastewater Treatment System Package 2 (KCWTSP2) under the Eleventh Malaysia Plan. KCWTSP1 covers a fully developed and densely populated area located at the Sarawak River's southern bank. Package 1 focuses on Kuching's central business district, from Satok to Wisma Saberkas and the Padungan area. It includes residential areas, commercial centers, and hotels. Package 1 consists of building a centralised wastewater treatment plant, a sewer network, and property connections to the sewer lines. This MYR530 million project began on September 30, 2008, and was completed on January 31, 2015. The Wastewater Treatment Plant is intended for a population equivalent (PE) of 100,000 people, located next to Jambatan Tun Datuk Patinggi Abang Haji Muhammad Salahuddin on a 10.9 hectares plot of land. This site has enough land to accommodate future expansion of up to four modules, for a total capacity of 400,000 PE [18] [19].

A sewer reticulation network collects and transports wastewater, including greywater and blackwater, to this treatment plant. The activated sludge system is used at the plant to process and treat wastewater. The plant's treated effluent must meet the requirements of Standard A of the Environmental Quality Act. The effluent will be refined further in a constructed wetland before being discharged into the Sarawak River.

The Sewer Network included in Package 1 has approximately 64.5 km and was designed using a gravity-flow system to collect and channel existing wastewater into public sewer networks and eventually to a centralized wastewater treatment plant. From 2833 property connections, the sewerage system collected 67,000 PE of wastewater (refer to **Figure 1**). The trunk sewer system is 7.7 km in total length, including a 280-meter-long Malaysia's longest under-river tunnel. The secondary and tertiary sewers are 5.4 km and 51.4 km long, respectively, with diameters ranging from 450 mm to 1500 mm. The pipes are either ductile iron cement lined (DICL) or High Density Polyethylene (HDPE). Tunnel Boring Machines may use the Slurry or Augering Method to install the trunk and secondary sewers. The traditional open-cut method will be used to install the majority of the tertiary sewer, with typical diameters ranging from 225 mm to 450 mm [20].

Sarawak State Government expanded sewerage coverage to Petra Jaya as part of the KCWTSP2. This MYR750 million project began on September 15, 2017 and is scheduled to be accomplished on September 14, 2023. The construction of the second module of the centralised sewage treatment facility, the sewer networks, and property connections are the major components of Package 2. Package 2 is connecting 27 large properties, including 16 in Kuching North and 11 in

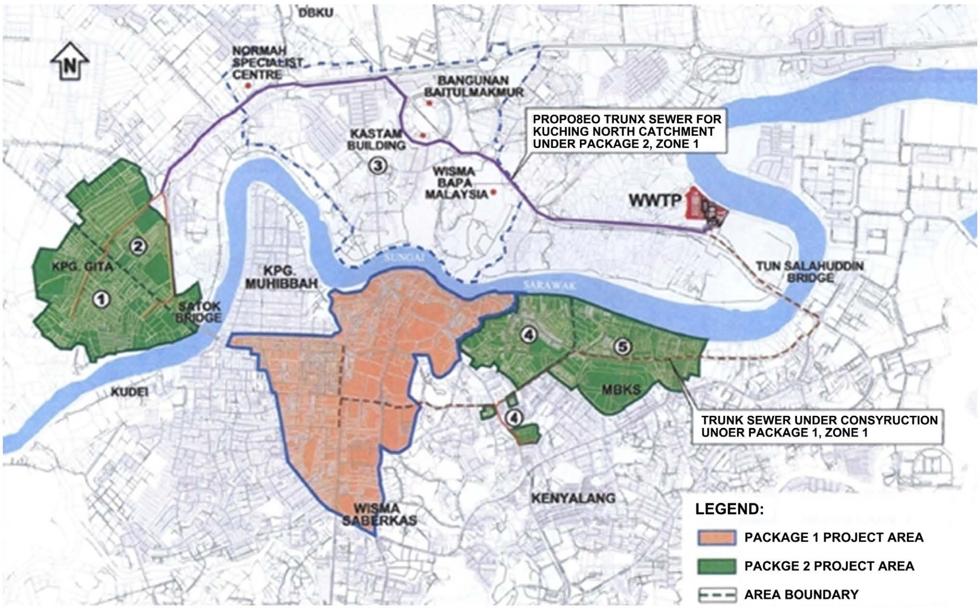

Figure 1. Coverage Area for KCWTSP1 and KCWTSP2 [21].

Kuching South. It also connects 2500 small properties in Kuching City North and 1800 small properties in Kuching City South.

The Sewer Network in Package 2 has a total length of approximately 56.1 km. The trunk and secondary sewers range from 450 mm to 1500 mm, with a trunk sewer length of 7 km and a secondary sewer length of 3.1 km. Similarly, trenchless technology will be used to install the trunk and secondary sewers. The tertiary sewer has a diameter ranging from 225 mm to 450 mm and a total length of 46 km, 30 km of which is in Kuching City North and 16 km in Kuching City South. The traditional open-cut method was used to install the tertiary sewer, with only a small portion installed using the trenchless method [21].

Meanwhile, the additional Darul Hana sewerage project, estimated to cost MYR20 million, is being implemented alongside Package 2. It will sewer 5000 PE from the Darul Hana new residential development area into the existing KCWTPP1. The works include the construction of a secondary and tertiary sewer network and property connections of existing sewer network under KCWTSP1 [22].

3. Treatment Process

Wastewater treatment, also known as sewage treatment, removes contaminants from wastewater before it is released into the environment so that it does not pollute nature (Safe Drinking Water Foundation, 2021). The treated water from KCWTSP1 is discharged into the Sarawak River, which is located beside the Centralised sewerage treatment plant, with the initiative to improve Sarawak River's quality by creating a cleaner and healthier Sarawak River. **Figure 2** depicts the layout of Kuching Centralised Sewerage Treatment Plant, located near to Tun Salahuddin Bridge in Petra Jaya [23].

Figure 2. Centralised sewerage treatment plant in Kuching.

Generally, there are four levels of wastewater treatment processes, including preliminary treatment, primary treatment, secondary treatment, tertiary treatment and sludge treatment, as presented in Figure 3.

Preliminary Treatment—Screens

The screening process at the inlet pumping station is the preliminary treatment. Plastic, feminine applicators, clothes, wood, and other materials are removed from the wastewater treatment plants through screens at the inlet pumping station [24]. There are two kinds of screens used: coarse screens and fine screens. Coarse screens with openings larger than 6 mm (1/4) are used to remove large solids, rags, and debris from wastewater, such as sticks, leaves, food particles, bones, plastics, and stones. Smaller materials such as cigarette butts, feces, and other organic matter are removed using fine screens with openings ranging from 1.5 mm to 6 mm. The proper selection and sizing of bar screens will ensure satisfactory mechanical and process performance and increase the efficiency of following treatment processes.

Primary Treatment—Headworks

The "headwork" of a wastewater treatment plant is the first stage of a complex process that reduces the level of pollutants in incoming domestic and industrial wastewater. Screening is done again at the headwork to remove fine material such as sticks, stones, sand, gravel, grit, and excessive amounts of oil and grease. Headwork's function is to remove inorganics from the wastewater stream to protect and reduce wear on subsequent treatment processes equipment. Pumps, mechanical screens, screening compactors, grit removal systems, and grit washing systems are among the equipment used in the headworks [25].

The engineer must ensure that the approach velocity of the wastewater to the screen does not fall below a self-cleaning value or rise sufficiently to dislodge screenings. Extremely low channel velocities may cause solids to settle in the channel ahead of the screen. At minimum flows, the velocity in the approach

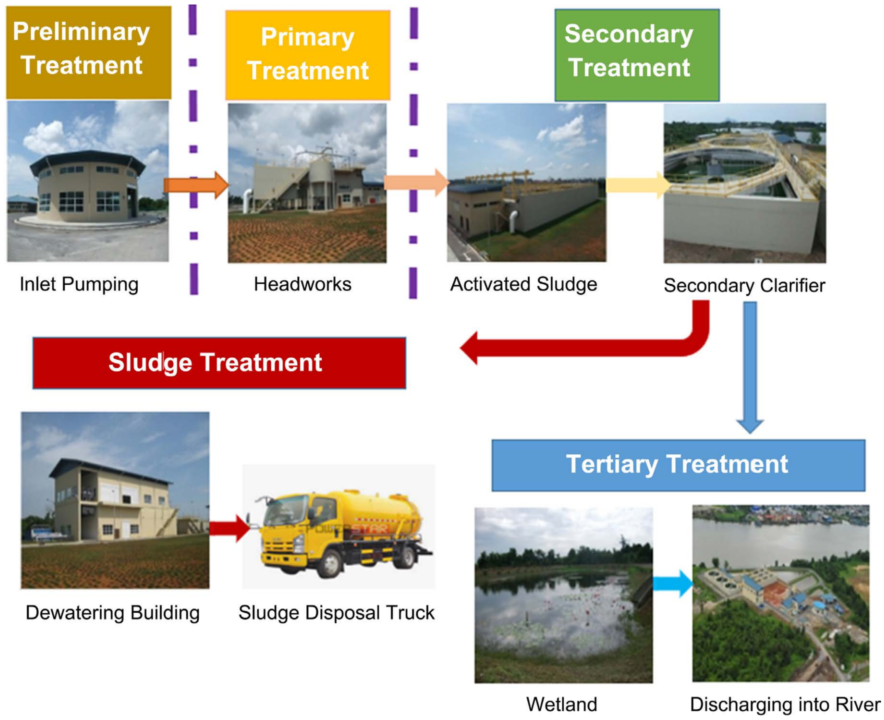

Figure 3. Treatment method of wastewater.

channel should ideally exceed 1.3 ft/s. This is to avoid grit and other solids from settling in the approach channel. Solids settling in the channel ahead of the screen may obstruct its operation and, in some cases, damage it.

Secondary Treatment—Activated Sludge and Secondary Clarifier

The activated sludge (AS) process is the most commonly used biological wastewater treatment process worldwide, including the KCWTPP1. The basic process has been widely adopted and further developed since its conception in the late nineteenth century and subsequent development into a full-scale process in 1913 by Arden & Lockett at the Davyhulme sewage treatment works in Manchester, a unique flexibility of operation.

To produce high-quality effluent, the activated sludge process feeds organic contaminants in wastewater to microorganisms. When wastewater is combined with a high proportion of microorganisms, a product known as mixed liquor is formed. Under aerobic conditions, microorganisms will biodegrade organic material by consuming it as food. During the biodegradation process, atmospheric air or oxygen is pumped into the activated sludge reactor via aeration to keep the solids in suspension. The oxygen aids bacteria in their reproduction and growth, and their rapid consumption of organic matter and conversion into carbon dioxide (CO_2). Microorganisms will multiply and clump together to form biological floc. The aerobic digestion of bacteria does not produce a pungent odor and is non-hazardous to the environment.

After some time, the mixed liquor is routed to a secondary clarifier, where the floc is allowed to settle at the tank's bottom as "activated sludge". The secondary clarifier is a large circular tank that separates treated wastewater from activated sludge from the aeration tanks. The main function of the secondary clarifiers is clarification and thickening the sludge [26]. Typical retention times are 5 - 14 hours in conventional units, rising to 24 - 72 in low rate systems [27]. During the settling process, approximately 80% of the bacteria are removed and disposed of as sludge. 20% of the sludge, which is teeming with high concentrations of hungry microorganisms, will be returned to the activated sludge tank to begin the treatment process all over again [28].

Sludge Treatment—Dewatering Building

Even though it appeared to be a solid material, the sludge produced in the secondary treatment process may contain up to 70% of water. Before disposal, the produced sludge will be directed to the dewatering building to extract the excess water in the sludge [29]. The sludge will undergo a drying process in the dewatering building and become solid dried sludge. The extracted water will be pumped back into the activated sludge tank for further treatment. Meanwhile, a biofilter is used at a dewatering building to absorb the odor from dry sludge before sending for sanitary landfill.

Tertiary Treatment—Wetlands

Tertiary treatment is a final stage of treatment that improves and enhances the quality of treated wastewater before it is discharged into the Sarawak River. The treated wastewater from the secondary clarifier will flow to the constructed wetland for further improving and polishing the water quality through natural microbial process treatment, such as nitrification and denitrification. The wetland is also referred to as nature's kidney because it removes pollutants from the water. Wetlands remove nitrogen and phosphorus through physical, chemical, and biological processes. As the water slowly flows through the wetland, the natural tertiary treatment processes involved are adsorb, transform, sequester, and remove nutrients and other chemicals.

The three main physical processes of nutrient removal are particle settling via sedimentation, volatilization (releasing as a gas into the atmosphere), and sorption [30]. Sorption is the process by which a nutrient adheres to a solid or diffuses into another liquid or solid. Chemical processes that occurred include transformations of nutrient form and chemical precipitation, which is the formation of a solid compound from a liquid via a chemical reaction. The main biological processes are uptake or assimilation by plants, algae, bacteria, and microbe transformation. These processes take place in the various wetland compartments, including water, biota (plants, algae, and bacteria), litter, and soil.

Wetland plants absorb inorganic nitrogen and phosphorus in the form of nitrate, ammonia, and soluble reactive phosphate via their roots and/or foliage and convert it into organic compounds for growth. However, this only provides temporary storage of the nutrients. When plants age and decompose, most of these assimilated nutrients are released back into the water and soils. About 10% to 20% of the nutrients are retained in hard-to-decompose plant litter and become incorporated into wetland soils, but this is relatively minor compared to other removal processes.

4. Results and Discussion

Table 1 shows the recorded detail treated volume of water obtained from KCWTPP1 from 2017 to 2020. It is noted that in 2019, the influent volume and dry sludge volume recorded was 4,447,827 m^3 and 928.86 tonnes, respectively, which is the highest compared to other years. While the lowest influent volume and dry sludge volume recorded was in 2017, with 3,914,263 m^3 and 274.63 tonnes, respectively. According to month, the highest recorded influent volume was in December 2019 with 561,376 m^3, while the lowest recorded was in January 2017 with 239,990 m^3. The highest recorded dry sludge volume was in April 2019 with 129.33 tonnes, while the lowest recorded was in April, May, and June 2017 with 0 tonnes. There are a few factors that influence the overall results, this includes weather or climate change, water consumption, chemical supply, and availability, etc. [31] [32].

Table 2 shows the minimum and maximum recorded results for 2017 to 2020 samples, including the temperature, pH, biological oxygen demand, chemical oxygen demand, suspended solid, phosphorus, nitrogen, ammoniacal nitrogen, nitrate nitrogen, and oil and grease. The highest value recorded temperature was in year 2019 with 33.30˚C and the lowest value recorded in 2018 with 23.70˚C. The highest and lowest pH value recorded was for the year 2017 with pH 7.84 and pH 5.51, respectively. The quantity of oxygen required by bacteria and other microorganisms when decomposing organic matter under aerobic (oxygen present) condition at a specific temperature is referred to as biochemical oxygen demand

Table 1. Detail treated volume of water at Kuching centralised sewage treatment plant from 2017 to 2020 [20].

Year	Treatment Process	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2017	Influent Volume (m^3)	239,990	373,520	346,308	304,462	335,619	319,739	295,510	347,284	308,512	329,791	333,580	379,948	3,914,263
	Dry Sludge Volume (tonne)	14.52	36.74	47.04	0.00	0.00	0.00	3.84	17.60	22.70	46.70	45.24	40.25	274.63
2018	Influent Volume (m^3)	388,318	370,522	373,517	344,688	304,852	297,929	317,316	296,263	314,571	366,080	414,976	424,312	4,213,344
	Dry Sludge Volume (tonne)	21.19	45.38	48.04	22.05	28.98	41.03	47.39	41.86	39.21	39.47	47.49	23.13	445.22
2019	Influent Volume (m^3)	406,934	367,916	341,797	321,698	312,905	348,906	340,609	323,418	321,584	447,224	353,450	561,376	4,447,817
	Dry Sludge Volume (tonne)	51.76	46.94	129.33	63.55	79.01	127.03	72.15	109.68	92.00	51.58	42.64	63.19	928.86
2020	Influent Volume (m^3)	420,846	442,032	345,722	256,448	292,626	336,244	336,824	331,296	400,912	393,368	383,752	413,128	4,353,198
	Dry Sludge Volume (tonne)	54.95	23.86	6.31	4.72	11.86	102.78	46.26	14.39	40.88	32.87	16.84	25.83	381.55

Table 2. Minimum and maximum sample temperature, pH, biological oxygen demand, chemical oxygen demand, suspended solid, phosphorus, nitrogen, ammoniacal nitrogen, nitrate nitrogen, and oil and grease [20].

Year	Temperature	pH (25˚)	Biological Oxygen Demand (BOD) mg/L	Chemical Oxygen Demand (COD) mg/L	Suspended Solids (SS) mg/L	Total Phosphorus mg/L	Total Nitrogen mg/L	Ammoniacal Nitrogen mg/L	Nitrate Nitrogen mg/L	Oil & Grease mg/L
2017	24.80 - 28.10	5.51 - 7.84	4 - 20	18 - 98	3 - 90	0.35 - 6.70	2.80 - 8.96	0.04 - 4.95	0.30 - 11.40	0
2018	23.70 - 28.30	6.53 - 7.27	4 - 11	18 - 49	3 - 18	0.36 - 3.10	-	0.03 - 2.88	0.00 - 2.60	0
2019	24.60 - 33.30	5.60 - 7.40	2 - 7.1	10 - 47	5 - 26.8	0.08 - 0.32	-	0.00 - 1.02	0.05 - 13.60	1.2 - 3.25
2020	28.00 - 30.00	6.20 - 7.30	2 - 23.4	11.3 - 92.9	1 - 50	0.09 - 1.06	-	0.06 - 1.26	0.23 - 8.22	1 - 2.6

*Note: Min - Max.

(BOD) [33]. Highest value of BOD was recorded for the year 2020 with 23.4 mg/L, while the lowest was recorded for 2019 and 2020 with 2.00 mg/L.

The quantity of dissolved oxygen required to oxidize organic chemical compounds such as petroleum is known as chemical oxygen demand (COD) [34]. The highest COD was recorded for 2017 with 98 mg/L, while the lowest chemical oxygen demand was recorded for 2019 with 10 mg/L. Small solid particles suspended in water as a colloid or owing to water motion are referred to as suspended solids [35]. Because of their enormous size, suspended particles may be removed via sedimentation. It is utilized as a water quality indicator. It is noted that the highest suspended solid is recorded for the year 2017 with 90 mg/L, while the lowest is recorded in the year 2020 with 1 mg/L.

The highest phosphorus recoded was in 2017 with 6.70 mg/L and the lowest recorded was in 2019 with 0.08 mg/L. On the other hand, the highest and lowest nitrogen recorded was in the year 2017 with 8.96 mg/L and 2.80 mg/L, respectively. For ammoniacal nitrogen, the highest recorded was in 2017 with 4.95 mg/L, while the lowest recorded was in 2019 with 0 mg/L. The highest value recorded for nitrate nitrogen was in 2019 with 13.760 mg/L, and the lowest recorded was in 2018 with 0 mg/L content. While for oil and grease, 2019 recorded the highest with 3.25 mg/L, and 2017 and 2018 recorded 0 mg/L content. Phosphorus, nitrogen, ammoniacal nitrogen, nitrate nitrogen is important as part of life cycle, however, it must be controlled to ensure it not becoming intoxicated nutrients [36].

Table 3 presents the acceptable discharge effluent conditions of Standards A published by the Environmental Quality Act 1974. As the acceptable parameters are compared to the observed discharge from Kuching Centralised Wastewater Treatment Plant Package 1 (KCWTPP1), it was discovered that the majority of the observed parameters meet the acceptable criteria for Standard A effluent for the years 2017, 2018, 2019, and 2020, with the exception of oil and grease. Only a few parameters were found exceeded the acceptable limits. It was discovered that the minimum PH value in 2019 was 5.60, which was less than the minimum requirement of 6.0. In 2020, the maximum BOD3 recorded was 23.4 mg/L, which exceeded the Standard A effluent maximum limit of 20 mg/L.

Table 3. Acceptable conditions of discharge effluent of standards A [37].

No.	Parameter	Standard A
1	Temperature	40˚C
2	PH Value	6.0 - 9.0
3	Biological Oxygen Demand (BOD_3)	20 mg/L
4	Chemical Oxygen Demand (COD)	120 mg/L
5	Suspended Solids (SS)	50 mg/L
6	Total Phosphorus	5 mg/L
7	Total Nitrogen	10 mg/L
8	Ammoniacal Nitrogen	10 mg/L
9	Nitrate Nitrogen	20 mg/L
10	Oil & Grease	1.0 mg/L

The maximum suspended solids concentration measured in 2017 was 90 mg/L, which is significantly higher than the Standard A effluent limit of 50 mg/L. However, the concentration of suspended solid effluent was significantly improved in the following years of 2018, 2019, and 2020. In total phosphorus, the maximum concentration recorded in 2017 was 6.70 mg/L, which exceeded the limit of 5 mg/L. However, the situation was improved significantly in the following years. Oil and grease concentration was only recorded in 2019 and 2020. Recorded results revealed that the oil and grease concentrations measured are higher than the standard A effluent limit. Hence, some enhancements to the treatment process are required to ensure that the effluent parameters meet the criteria of Standard A effluent in future.

5. Conclusion

This review paper demonstrates that the operation of KCWTPP1 had successfully treated and improved the wastewater before discharging it into the nearby Sarawak River. Since its inception in 2017, KCWTPP1 has treated a total of 3,914,263 m^3, 4,213,344 m^3, 4,447,817 m^3, 4,353,198 m^3 of wastewater in 2017, 2018, 2019, and 2020, respectively. Furthermore, the total amount of sludge treated in 2017, 2018, 2019, and 2020 is 274.63 tonnes, 445.22 tonnes, 928.86 tonnes, and 381.55 tonnes, respectively. Except for the oil and grease parameter, most of the observed effluent discharge parameters meet the criteria for Standard A effluent of the Environmental Quality Act of 1974. The discharge effluent for two parameters, suspended solids, and total phosphorus, were not properly treated during the project's first year of operation. However, the treated water quality of these two parameters improved over time. Only the oil and grease parameter is still unable to meet the standard A effluent criteria. Therefore, some improvements in the treatment process are required to treat oil and grease parameters and ensure that only Standard A effluent will be discharged into Sarawak River in the future.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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