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Evaluation of poly aluminium chloride (PAC) and polyacrylamide (PAM) in coagulation-flocculation processes for sewage wastewater treatment

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ABSTRACT

The increasing population and industrial activities in Malaysia are putting strain on the country’s sewage wastewater treatment, leading to environmental pollution and public health risks. Indah Water Konsortium Sdn. Bhd. has been commissioned assigned with sewage treatment plant (STP) operation which uses biological process of Sequence Batch Reactor (SBR). Meanwhile, research on chemical process for the sewage treatment using poly aluminium chloride (PAC) and polyacrylamide (PAM) that acted as coagulant and flocculant respectively, in Jar Test method was carried out. The purpose of this research was to evaluate the possible improvement of chemical process on suspended solids removal beyond the capabilities of the existing SBR system. These two chemicals were varied in dosage amount, and used to ensure the suspended solids are bound together to form a bigger floc and settle out. Turbidity, Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Total Suspended Solid (TSS) and pH value were analysed to meet the standard B limit set by the Department of Environment (DOE). Results showed that the most effective impact of coagulant and flocculant was the treated wastewater in Jar 5 using only 16 mg/L of PAC and 0.04 mg/L of PAM were used as coagulant and flocculant, respectively, resulting the value of the turbidity, pH, COD, BOD, and TSS was 2.00 NTU, pH 6.22, 2.00 mg/L, 5.22 mg/L, and 2.00 mg/L, respectively.

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1. INTRODUCTION

Freshwater resources are declining due to rapid population growth, urbanization, exhaustive water consumption, and climate change (Mishra et al., 2023). These factors are straining our water supply and threatening our future. Indeed, the urbanization and industrialization have significantly increased water pollution, particularly wastewater with high COD and BOD levels (Suman et al., 2023). This wastewater cannot be directly released into rivers, ponds, or any surface water as it would severely harms the aquatic ecosystem and water supply. It must therefore be treated in sewage treatment plants (STPs) to meet the parameters set by environmental protection agencies. In previous report, Malaysia has a population of 28.3 million based on the Report of Census 2010 by the Department of Statistics. The estimated volume of wastewater generated by municipal and industrial sectors is 2.97 billion cubic meters per year (Azman et al., 2013). Sewage wastewater is a broad term that refers to any water that has been used and contaminated by human activity. It can include domestic wastewater, industrial wastewater and agricultural wastewater. The sewage wastewater studied in this research is primarily domestic wastewater collected from urban areas. This category of wastewater generally consists of residential discharges, including greywater and blackwater, as well as limited commercial sources. The large volume of sewage wastewater in metropolitan areas makes sewage wastewater treatment more challenging and requiring massive STPs (Ishak et al., 2021).

Currently, Malaysia has 7000 municipal STPs, covering most major cities and designed to serve 26.9 million population equivalents with a daily maximum volume of 9.2 million cubic meters (Rahmat et al., 2022). The economic and environmental performance of the STP is a critical indicator of their overall success. The sustainable wastewater facilities achieve consistent operation through energy savings, consumption reduction, and resource recovery could reducing operating costs. Meanwhile, in term of environmental performance, parameters of treated water such as Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS) and pH value need to be monitored for ensuring that the treated sewage meets the requirements for safe discharge into receiving water bodies (Fallahiarezoudar et al., 2022). These parameters need to meet national water quality standards for Malaysia established by the Department of Environment (DOE), which are outlined in the Environmental Quality Act 1974 and specific regulations like the Environmental Quality (Sewage) Regulations 2009. Indah Water Konsortium (IWK) is a Malaysian government-owned company that manages and maintains the country's public sewage systems. The company collects, processes, and disposes of household wastewater through a nationwide network of sewerage pipelines, pumping stations, and STP (Indah Water Portal | Overview, 2023).

IWK prioritises wastewater management for public health and the environment. In fact, the STP operated by IWK uses a sequencing batch reactor (SBR) system. The SBR system is widely use in STP process for its promising organic pollutant removal capabilities due to their microbial metabolism and intermittent aeration tank. The tank is equipped with aeration and mixing equipment to help the bacteria break down the organic matter in the wastewater (Yang et al., 2022). The SBR plant also known as a biological process that consists of four steps: filling, aeration, settling, and decanting (Tantak et al., 2014). In previous studies, the SBR also reported to combine with other process such as aerobic granular sludge (Lei et al., 2021) and microalgal-bacterial consortium (Du et al., 2022) in order to enhance the performance of STP. Meanwhile, this research aims to implement a chemical process for sewage wastewater treatment using the coagulation and flocculation process as an alternative method to the biological treatment process, specifically the SBR system currently used by IWK for sewage wastewater treatment. The SBR process is effective for reducing organic matter through biological degradation but can be limited in its ability to remove suspended solids and fine particles, which can affect water clarity and overall effluent quality.

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The coagulation and flocculation processes overcome this limitation by physically aggregating and settling these particles, making them easier to remove. Coagulation, the first-responding superhero of wastewater treatment, transports and disperses coagulants using specific chemicals injected into the water. These chemicals interact with water to produce fascinating results, clearing the water of suspended solids and pollutants. As result, it prevents the negatively charged particles from maintaining their stability by eliminating their charge (Shabangu et al., 2022). This causes the particles to aggregate into larger clumps called flocs. Flocculation is a crucial step in wastewater treatment, following coagulation. During flocculation, the flocs formed in coagulation collide and stick together, growing larger and denser (Tripathy & De, 2006). This is achieved by adding a flocculant to the wastewater and gently mixing it. The flocculant acts like glue, bridging the gaps between flocs and causing them to merge. Larger and denser flocs settle more quickly, enabling their removal from the wastewater (Lee et al., 2014). The flocs can be removed from the water using a variety of methods, including sedimentation, flotation, and filtration.

Poly aluminium chloride (PAC) and polyacrylamide (PAM) are widely used coagulants and flocculants, respectively, in wastewater treatment to achieve high-quality treated water (Liu et al., 2023; Nti et al., 2021). PAC, an inorganic polymer coagulant, is particularly effective due to its ability to neutralise the charges on colloidal particles, thereby facilitating their aggregation into microflocs. This makes PAC highly efficient in the initial stages of the coagulation process. Its unique electronic structure and relatively simple preparation process contribute to its popularity as one of the most effective coagulants for water treatment (Wang et al., 2022). While PAC and PAM have been commonly used as coagulants and flocculants, respectively, limited research has focused on determining their optimal dosages for specific STP, particularly in the context of local treatment plant conditions (Habibi et al., 2024; Ji et al., 2024). Thus, this study identified the most effective dosages of PAC and PAM for achieving efficient coagulation and flocculation. The treated water was evaluated for key parameters such as turbidity, pH, BOD, COD, and TSS, in compliance with DOE standards. The novelty of this work lied on its application to local STP, providing an alternative approach to improving treatment efficiency with tailored chemical dosing.

2. METHODOLOGY

2.1 Wastewater and chemicals

As illustrated in Fig. 1, a wastewater was collected at the inlet point of the aeration tank before the aeration process commenced. This aeration tank is part of the IWK sewage treatment facility located in Seksyen 7, Shah Alam, Selangor, Malaysia. The wastewater was subjected to a coagulation-flocculation process using the JLT6 Jar Test apparatus, with six jars containing varying concentrations of the coagulant and flocculant. Key water quality parameters which are turbidity, total suspended solids (TSS), pH, chemical oxygen demand (COD) and biochemical oxygen demand (BOD) were measured for both the wastewater and treated water. Chemicals used in the BOD analysis included ferric chloride, calcium chloride, magnesium sulphate and phosphate buffer solution. Meanwhile poly aluminium chloride (PAC) was used as the coagulant, and polyacrylamide (PAM) was used as the flocculant. All chemicals utilised in this research were purchased from Sigma Aldrich, Malaysia.

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Figure 1: Wastewater from aeration tank in IWK

Source: Authors' own data

2.2 Jar test method

Six wastewaters were tested for the coagulation-flocculation process, each subjected to different dosages of coagulant and flocculant which are PAC and PAM respectively, as presented in Table 1. Each sample was placed in a 1L jar within the JLT6 Jar Test apparatus. The jar testing procedure consists of three phases: rapid mixing, slow mixing, and settling. The jars were carefully set up on the Jar Test apparatus, ensuring the stirrers did not contact the jar walls. During the rapid mixing phase, the coagulant was added using a pipette, and the JLT6 was set to stir at 140 rpm for three minutes. This was followed by the slow mixing phase, where the flocculant was added, and the JLT6 speed was reduced to 70 rpm for five minutes. After the mixing phases, the apparatus was stopped, allowing the water to settle for 15 minutes, resulting in treated water that was then ready for further testing of water quality parameters. The Jar Test method was selected due to its reproducibility and controlled conditions, which allow for a systematic study of the coagulation-flocculation process. By testing six different concentrations of PAC and PAM, the study aimed to identify the optimal chemical dosages for effective treatment.

Table 1: Dosage of coagulant and flocculant for each jar

Jar	Coagulant/PAC (mg)	Flocculant/PAM (mg)
1	0	0
2	4	0.01
3	8	0.02
4	12	0.03
5	16	0.04
6	20	0.05

Source: Authors' own data

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2.3 Parameter analysis

Five parameters were analysed for wastewater and treated water which were turbidity, chemical oxygen demand (COD), biochemical oxygen demand (BOD), total suspended solids (TSS), and pH value. The analysis of these parameters followed standard procedures commonly used by other researchers in water quality assessments, ensuring the reliability and comparability of the results (Bakar et al., 2020). For the turbidity analysis, 10mL of each wastewater was filled in closed glass cell and tested using Turbidimeter HACH 2100P. Before testing, ensure there are no air bubbles inside the water and wipe the cell body with a soft tissue to avoid errors, as dirt can mislead the equipment. The reading was repeated for three times and recorded. pH values for wastewater and treated water were measured three times each sample and average value was recorded. The pH reading was measured using HACH Sension3 pH meter and the probe was rinsed with distilled water before and after use to ensure no contamination.

For the COD analysis, it was measured using HACH DR2800 Spectrophotometer. The wastewater and treated water were added into 10mL vial of Low Range (LR) COD reagent and incubated into COD incubator for 2 hr prior measurement. BOD solutions were prepared by diluting 40mL each of ferric chloride, calcium chloride, magnesium sulphate, and phosphate buffer solution into 4L of distilled water. This preparation ensures that essential nutrients and buffering capacity are provided, supporting microbial activity during the BOD test. Each solution was then aerated with an air pump for 1 hour to introduce dissolved oxygen, which is necessary for the microorganisms to decompose the organic matter in the sample. Exactly 290 mL of BOD solution was mixed with 10 mL each of wastewater and treated water and left for incubation inside the incubator for 5 days to measure a DO level in day 5. Both reading of DO in day 0 and day 5 was recorded using YSI 5000 DO Meter and the BOD was calculated using Eq. (1).

$$\mathrm{BOD}\left(\frac{\mathrm{mg}}{\mathrm{L}}\right) = \frac{\mathrm{DO_0} - \mathrm{DO_5}}{\mathrm{P}} \quad (1)$$

where the DO_0 and DO_5 are the reading of dissolved oxygen at day 0 and day 5, respectively and P is the decimal dilution factor of the wastewater or treated water used.

The last parameter of TSS was analysed using HACHDR2800 Spectrophotometer for all the 10 mL of each wastewater and treated water. The reading was repeated for three time and the average value was recorded.

3. RESULTS AND DISCUSSION

3.1 Jar test performance

The jar test revealed a clear difference in floc settling across the samples. Fig. 2 – 4 highlight the results: Fig. 2 shows the initial state of the samples before treatment, Fig. 3 captures the floc settling process after 15 minutes of standing at 0 rpm, and Fig. 4 illustrates the fully settled samples.

In particular, Jar 1, which served as the control and contained untreated water which exhibited the slowest settling and smallest flocs. This was observed by visually monitoring the floc formation and settling behaviour during the 15-minute settling phase. The size of the flocs was evaluated by comparing their visual appearance to the treated samples. In Jar 1, the flocs were observed to be smaller and more dispersed, with a much slower rate of aggregation, as no coagulant or flocculant was introduced to promote particle binding. These findings suggest that the addition of chemicals in the treated jars significantly enhanced both the speed and efficiency of floc formation and sedimentation compared to the natural settling process observed in Jar 1.

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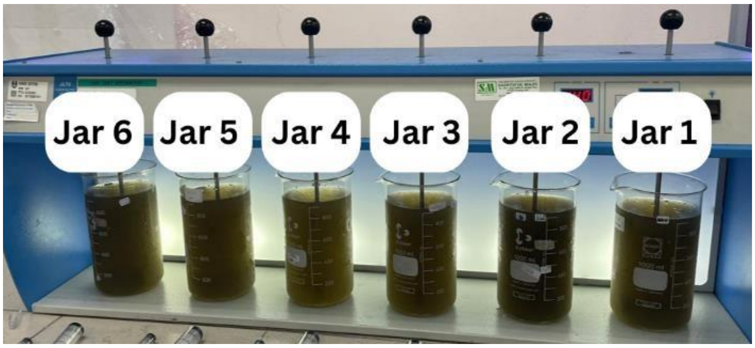

Fig. 2. Sample water in 6 jars before jar test
Source: Authors' own data

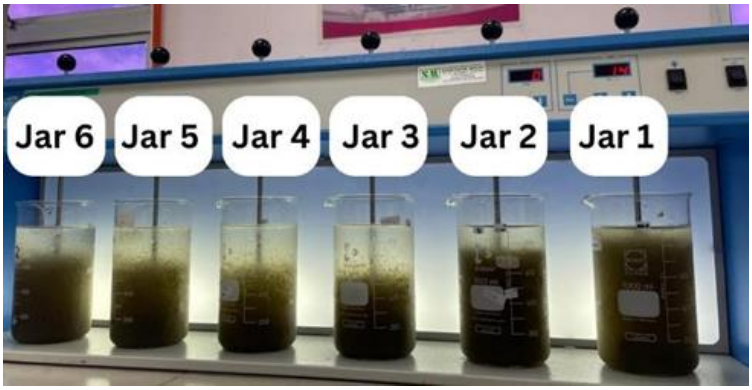

Fig. 3. Jar test at 0 rpm, 15 minutes left
Source: Authors' own data

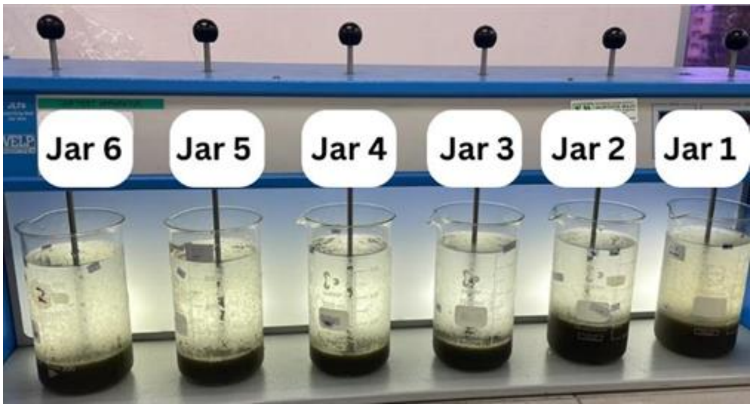

Fig. 4. Jar test after 15 minutes of settling
Source: Authors' own data

After 15 minutes settling in the jar test as shown in Fig. 3, it was evident that the flocs in Jar 1 which was the control without chemicals, were significantly higher than those in the other jars. This suggests that the coagulant and flocculant used in the other jars effectively promoted floc formation and settling. In particular, Jar 3 with the specific dosage of 8 mg and 0.02 mg for coagulant and flocculant, respectively,

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exhibited the fastest settling which indicated potential for optimal chemical application. Such a combination promoted more rapid floc formation and settling which indicated efficient coagulation-flocculation process at this dosage. However, to definitively optimise coagulant and flocculant dosages for both settling rate and treated water quality, further analysis on turbidity, pH, TSS, COD, and BOD were essential. After 15 minutes of settling as illustrated in Fig. 4, the jar test revealed contrasting results. While flocs had settled to the bottom of every jar, the clarity of the treated water differed significantly. In particular, Jar 1 as the control containing untreated water, remained visibly turbid. Its more yellowish colour as compared to the other jars suggested the presence of suspended particles which were not effectively removed by natural processes. This highlighted the effectiveness of the coagulant and flocculant used in the other jars in promoting sediment formation and enhancing water clarity (Sun et al., 2019).

In theory, poly aluminium chloride (PAC) acts as coagulant which neutralises charges on suspended particles allowing them to attract and clump together. This sets the stage for floc formation. Then polyacrylamide (PAM) as flocculant acts like glue which binds these small clumps into larger and heavier flocs. As seen in Fig. 4, after 15 minutes of settling, these larger flocs sank to the bottom and thus leaving a clearer water above. With increasing floc size and stronger bonds, the turbidity steadily decreases and the flocs themselves become more visible (Barros et al., 2022).

3.2 Turbidity, pH, and TSS analysis

To visualise the effects of coagulation and flocculation on turbidity, pH and TSS parameters data are presented in Table 2 which reveals a clear trend as most tested parameters decreased steadily as the combined dosage of coagulant and flocculant increases. This suggests that these chemicals effectively improved water quality. Jar 1 which represented the initial untreated water was exhibited the highest levels of turbidity, pH, and TSS. As expected, both PAC and PA significantly reduced these pollutants in the other jars. Among the six jars, Jar 3 achieved the lowest turbidity value of only 1.72 NTU. This was further evident in Figure 4, where the difference in water colour was apparent. Jar 1 of untreated water appeared cloudy and yellowish, whereas Jar 3 presented an almost clear appearance. This drastic improvement in Jar 3 showed the efficacy of the coagulant and flocculant in destabilising and removing suspended particles which effectively clarifying the water (Saxena & Brighu, 2020).

Table 2. Analysis data for turbidity, pH and TSS of the samples

Jar	Turbidity(NTU)	pH	TSS (mg/L)
1	20.30	6.63	13.00
2	3.34	6.38	7.00
3	1.72	6.31	5.00
4	1.80	6.27	2.00
5	2.00	6.22	2.00
6	2.21	6.16	1.00

Source: Authors' own data

However, the success of this process depends on various factors which is from the type of wastewater being treated to the pollutant mixture within it and even the specific operating conditions of the coagulation and flocculation process (Soros et al., 2019). While coagulation and flocculation are effective mechanisms against turbidity, however they were not absolute. Martín et al. (2011) stated that some level of turbidity may persist. To achieve near-zero turbidity for high-quality water, additional processes like sedimentation and filtration are often necessary (Martín et al., 2011). This study demonstrated that injecting coagulants

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and flocculants significantly improved turbidity reduction as compared to untreated water. Among the treated jars (2-6), Jar 3 with 8 mg of coagulant and 0.02 mg of flocculant achieved the highest turbidity removal of 92%, which could not achieve complete removal. This highlighted the importance of considering additional treatment steps for specific water quality requirements.

Additionally, this study also examined the changes in the pH level of the treated water in response to different chemical dosages. Table 2revealed that there were no significant changes in pH values across all the samples. This agrees with Ma et al. (2012), who pointed out that coagulation and flocculation typically have minimal impact on pH. These processes primarily focus on destabilising and clumping suspended particles which is not altering the water acidity or alkalinity. pH ultimately depends on the concentration of hydrogen ions which remains largely unchanged by the added chemicals. However, coagulation and flocculation can even slightly improve pH in some cases. Aditya & Kartohardjono (2018) explained that the formed flocs can trap acidic or basic particles which thereby influencing the overall pH (Aditya & Kartohardjono, 2018). In this study, this might contribute to the observation in Jar 6 which contained the highest amount of chemicals dosage for 20 mg of PAC and 0.05 mg of PAM. Therefore, Jar 6 demonstrated the highest pH removal of 7% which was significant considering this small change within the context of minimal chemical impact on the pH. While coagulation and flocculation processes are effective in removing suspended solids and other pollutants, their influence on pH is generally limited, as supported by previous studies that have shown similar findings (Fallahiarezoudar et al., 2022; Rahmat et al., 2022). Other factors such as the initial pH of the wastewater and the presence of specific ions expected play a bigger role in determining the pH value in treated water.

The TSS analysis which is another crucial parameter closely linked to turbidity (Chaitra et al., 2017), as decrease in turbidity within the wastewater often indicates a corresponding decrease in TSS. Table 2 illustrated a decreasing trend in turbidity generally corresponds to a decrease in TSS. However, unlike turbidity measured by the HACH 2100P Turbidimeter, while the TSS measurement captured a wider range of suspended particles which included which were invisible to the turbidimeter but detectable by the HACH DR2800 Spectrophotometer. Among the treated water, the lowest turbidity was exhibited at Jar 3 of 1.72 NTU, while the lowest TSS was exhibited at Jar 6 of 1.0 mg/L. The TSS encompasses sand, silt, clay, organic matter and even bacteria which is making it a vital indicator of water quality. High TSS levels indicate significant suspended matter by impacting aquatic life and ecosystem health (Bakhtiari et al., 2009). High TSS in water treatment disrupts chemical effectiveness in coagulation and flocculation by hindering efficient removal of particles and potentially leaving contaminants behind. Data in Table 2 indicates that Jar 6 was treated with 20 mg of coagulant and 0.05 mg of flocculant had achieved the highest TSS removal percentage of 92%. This optimal combination signifies a more efficient treatment process that ultimately leading to enhanced water quality for consumers.

High removal rates of turbidity and TSS indicate that a significant amount of suspended particles which include those containing organic materials are being removed. Since TSS removal primarily targets insoluble particles and this process contributes indirectly to the reduction of soluble organic materials as well by aggregating fine particles that may contain or be associated with dissolved organic compounds (Pushpalatha et al., 2022).

3.3 BOD analysis

Among the key parameters determining the quality of treated wastewater, the BOD is a crucial one. Table 2 below presents these values alongside the dissolved oxygen (DO) levels on day 0 and day 5 of incubation. As the control sample (Sample 1) which contained no coagulant or flocculant had the highest BOD value of 26.39 mg/L. Meanwhile, other samples treated with coagulation and flocculation processes showed a decrease in BOD values. This suggests some degree of organic matter removal through these combined processes (Sillanpää et al., 2018). Particularly, samples with higher dosages of both chemicals

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(Samples 5 and 6) have achieved the lowest BOD values which are 5.22 mg/L and 11.60 mg/L, respectively, indicating their greater effectiveness in removing organic matter.

Table 2. Dissolved oxygen on 0th and 5th day, and final value of BOD

Sample	DO_0 (mg/L)	DO_5 (mg/L)	BOD (mg/L)
1	8.22	7.31	26.39
2	8.27	7.82	13.05
3	8.24	7.76	13.92
4	8.25	7.71	15.66
5	8.29	8.11	5.22
6	8.24	7.84	11.60

Source: Authors' own data

Fig. 5 illustrates the removal percentage of BOD value for treated sample over untreated sample. From the figure, Jar 5 had exhibited the highest removal percentage of 80% which indicated the lowest BOD value of 5.22 mg/L. The high BOD value can be attributed to various factors with the source water playing a significant role. In this instance, the sample originated from Indah Water Konsortium at Seksyen 7 Sewage Treatment Plant (STP) which caters to both residential and commercial users. Sewage is loaded with organic matter such as food waste and human waste, while the industrial effluents provide a readily available carbon source for microbial growth (Srivastava et al., 2020). These microorganisms which is present during aerobic respiration decompose the organic matter leading to the consumption of DO that present in the water body. This depletion of DO poses a significant threat to aquatic life as their survival hinges on its presence (Zareth et al., 2020). Therefore, the lower BOD value indicates higher water quality which found at Jar 5 with the contain of 16mg of PAC and 0.04mg of PAM.

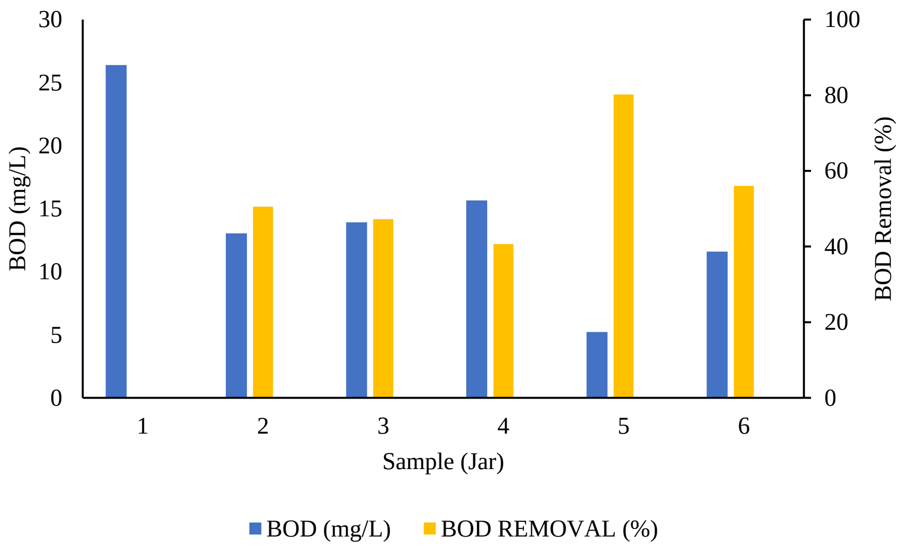

Fig. 5. BOD values BOD removal percentages for all samples

Source: Authors' own data

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3.4 COD analysis

The COD analysis is also a crucial parameter in wastewater treatment analysis. It provides an indirect measure of the amount of oxygen required to chemically oxidize these organic compounds completely. Figure 5 illustrates the removal percentage of BOD value for the treated sample over untreated sample. Among the treated sample, Jar 6 with the contain of 20mg of PAC and 0.05mg of PAM had the lowest COD value of 1 mg/L. Meanwhile, Jar 2 had remained the untreated of COD value at 23 mg/L. Jar 3 exhibited a reduction to 13 mg/L, while Jar 4 demonstrated fluctuations which reached a high value of 19 mg/L. The persistence of high COD values in Jars 2 and 4 despite their demonstrated turbidity reduction have indicated the presence of intractable organic matter. These organic compounds resist removal by the employed coagulant and flocculant dosages. This aligns with research by (Gohatre, 2016), who suggest that such resistant matter might require extended mixing times beyond the standard durations used in these experiments for effective neutralisation and floc formation.

The high COD value in water increase concerns due to their potential for detrimental ecological impacts. Al-Sareji et al. (2020) highlighted that COD can encompass nutrients like nitrogen and phosphorus which is acting as fertilizers for aquatic ecosystems. When present in excess, these nutrients can trigger eutrophication that characterised by rapid algae and plant growth (Al-Sareji et al., 2020). This phenomenon depletes DO and disrupting the ecological balance. Fortunately, Jars 5 and 6 demonstrated excellent performance by achieving remarkable COD removal percentage of 91% and 96%, respectively. This indicates that the specific dosages employed in these jars effectively addressed the organic pollutants by mitigating potential environmental risks. Furthermore, the higher COD removal compared to BOD removal were observed in most jars is primarily due to the coagulation and flocculation process which is specifically designed to target and remove chemically oxidizable substances. This makes coagulation-flocculation particularly efficient for treating contaminants that cannot be easily broken down biologically which is resulting in notable COD reduction (Bahrodin et al., 2021).

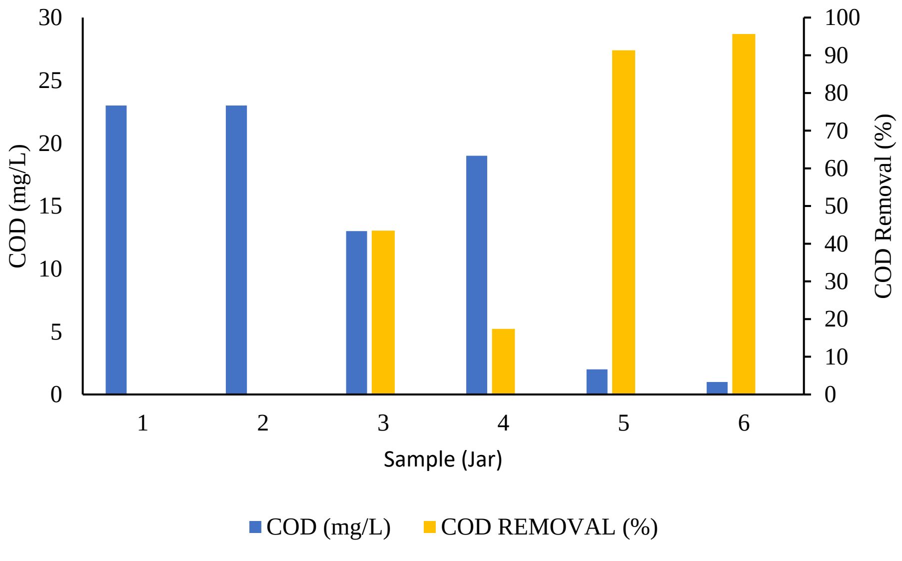

Fig. 6. COD values COD removal percentages for all samples

Source: Authors' own data

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3.5 Optimisation of chemical dosage

In this study, the optimisation of chemical dosage was achieved by experimentally varying the concentrations of PAC and PAM across a series of Jar Tests. The optimal dosage was determined by analysing the results obtained from the tests and identifying the chemical concentration that yielded the best overall improvement in water quality, with the least residual turbidity, reduced TSS, and acceptable levels of COD and BOD, while maintaining pH levels within regulatory standards.

A dosage of 16 mg PAC and 0.04 mg PAM as coagulant and flocculant, respectively emerged as the optimum dosage in Jar 5. This treatment consistently achieved significant improvements in turbidity, TSS, BOD, and COD removal as demonstrated by removal percentages of 90%, 85%, 80%, and 91%, respectively. Notably, these reductions directly address the key concerns of high turbidity, TSS, BOD, and COD which are prevalent in the untreated water. The Jar 5 showed an exceptional performance in achieving a 91% COD removal as the optimal choice for producing high-quality treated water. This aligns with IWK commitment to adhering to the stringent effluent quality standards established by the Environmental Quality Act 1974 (Standard B). As the treated wastewater from this WTP at Seksyen 7 in Shah Alam, Selangor is released to klang river, adherence to these standards is crucial for safeguarding the ecological well-being of the river and its surrounding environment.

Table 3 compares the parameters of treated water in Jar 5 which achieved with an optimal dosage of 16 mg PAC and 0.04 mg PAM to both the internal limits of IWK Seksyen 7 and the Standard B limits set by the Department of Environment (DOE). The treated water closely aligns with the IWK internal limits for all parameters which is suggesting the feasibility of this process to achieve high-quality water compliant with DOE standards. Notably, the treated water in this process shows the lowest COD value compared to IWK sewage plant treatment, likely due to the targeted application of coagulant and flocculant chemicals. This indicates that the chosen dosage effectively achieved significant pollutant removal, contributing to high-quality water production. Meanwhile, the untreated wastewater may initially meet Standard B, the coagulation-flocculation process offers value by improving effluent quality by ensuring flexibility in meeting various regulatory standards and providing resilience against fluctuations in influent quality.

Table 3. Comparison of water quality to the Integral limit and Standard B limit

Parameter	Jar 5	Internal limit average	Standard B
pH	6.22	6.3	5.5 – 9.0
Suspended Solids (mg/L)	2	3	100
BOD_5 at 20℃ (mg/L)	5.22	5.2	50
COD (mg/L)	2	24.4	200

Source: Authors' own data

4. CONCLUSIONS

This study investigated the effectiveness of chemical coagulation and flocculation in improving water quality within IWK sewage treatment plant which is located at Seksyen 7 in Shah Alam. Six samples from aeration tank were treated using various PAC and PAM dosages and then analysed the treated water for turbidity, pH, TSS, BOD and COD parameters. An overall result revealed that Jar 5 with 16 mg/L PAC and 0.04 mg/L PAM as the most effective combination. This dosage achieved impressive reductions in all

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parameters of turbidity and TSS reaching 2 mg/L each, COD dropping to 2 mg/L, BOD decreasing to 5.22 mg/L, and pH settling at 6.22. Notably, Jar 5 also exhibited faster floc settling compared to the others treated water, further demonstrating the positive impact of the chemicals.

Furthermore, comparison with IWK internal limits and the Standard B limit confirmed that Jar 5 was treated water that met all quality requirements. This suggests that incorporating coagulant and flocculant into their existing mechanical process (Sequence Batch Reactor) could significantly enhance wastewater treatment efficiency and ensure high-quality discharge into Sg. Klang.

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CONFLICT OF INTEREST STATEMENT

The authors agree that this research was conducted in the absence of any self-benefits, commercial or financial conflicts and declare the absence of conflicting interests with the funders.

AUTHORS CONTRIBUTIONS

Siti Halwa Othman: Methodology, formal analysis, investigation, and writing-original draft; **Noor Fauziyah Ishak**: Data analysis and validation; supervision, writing- review and editing; **Muhammad Iqhmal Borhan**: Writing- review and validation.

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