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Proceeding Paper

# Effective Microorganism (EM) Technology for Lake Conservation and Water Quality Restoration †

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**Abstract:** Water quality is a crucial determinant in decision-making processes aimed at optimizing resource allocation across various industries. Pollutant impurities that hinder the sufficient supply of water have a deleterious impact on the quality and are damaging to living species, especially aquatic life. Various chemical and biological treatments are used to reduce water pollution levels. A technology involving a mixture of anaerobic and aerobic beneficial microbes is becoming popular for its eco-friendly characteristics. Effective Microorganism (EM) technology utilizes naturally existing microorganisms that can purify and restore the environment. The study investigated the application of Effective Microorganism-Activated Solution (EMAS), TeMo Decomposer (TeMo), and Lactic Acid Bacteria (LAB) to enhance water quality. Additionally, microbial testing will be carried out to identify bacteria present in each EM. EM-based rehabilitation of polluted and degraded water bodies significantly contributes to the restoration of aquatic habitats and ecosystems. This study aimed to assess the water quality at Tasik Alumni, Kampus Pauh, Perlis, Malaysia. Four sampling points in Tasik Alumni were chosen to reflect the water quality status of the lake. The sampling was conducted once at four points locations in Tasik Alumni. Seven water quality measures, including pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammoniacal nitrogen ($NH_3$-N), total suspended solid (TSS), and turbidity, were analysed ex-situ and categorised according to Water Quality Index (WQI) and National Water Quality Standard (NWQS) classifications. The Tasik Alumni was categorised as mildly contaminated. The results clearly showed the efficiency of this technique in restoring and conserving water quality in a degraded or polluted lake.

**Keywords:** effective microorganisms; effective microorganism activated solution; TeMo decomposer; lactic acid bacteria; water quality index; national water quality standard

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## 1. Introduction

The utilisation of Effective Microorganism (EM) technology has been extensive in improving the quality of lake water and advocating for the conservation of lakes. According to Zakarya et al. [1], one of the potential strategies for enhancing river and lake water quality is EM technology, which has been widely praised in comparison to other conventional methods due to its eco-friendly nature and low inputs, costs, and capital. In 1980, Professor Dr Teruo Higa of the University of Ryukyus, Okinawa, Japan, created the notion of EM. Microorganisms are classified as decomposing or degenerative, opportunistic or neutral, or constructive or regenerative. EM is classified as regenerative since it may prevent degradation in any type of substance to sustain the health of both live creatures and the environment [1].

According to Dobrzyński et al. [2], EM comprises roughly 80 kinds of microorganisms that can purify and improve nature, including photosynthesizing bacteria, LAB, and fermenting fungi. The application of EM has been found to facilitate the fast decomposition of organic materials. The EM utilized in this investigation are Effective Microorganism Activated Solution (EMAS), TeMo Decomposer and LAB.

The main aim of this study is to evaluate the EM formulation to assess the water quality in Tasik Alumni by investigating seven parameters. The research objectives of this study are to prepare three different types of EM and identify the bacteria and fungus for each of them. Thus, to determine which dosage achieved a better percentage removal for turbidity, $NH_3$-N, TSS, BOD, COD, as well as increased DO and pH, and to assess the water quality status of UniMAP Lake when treated with Effective Microorganisms, a comparison was made with the National Lake Water Quality Criteria and Standards (NLWQS) and the Water Quality Index (WQI). The objective of incorporating EM technology is, not only to restore water quality, but also to guarantee the enduring conservation and sustainability of lake ecosystems. This strategy is in line with international efforts to safeguard freshwater resources and uphold the ecological balance in natural water bodies.

## 2. Experimental

### *2.1. Effective Microorganisms Activated Solution (EMAS)*

The preparation of EMAS contained concentrated EM-1 solution, water, and molasses. The EMAS was a mixture of molasses and EM-1 in non-chlorinated water. The product was stored in a warm environment between 20 and 35 °C. The suspension had a pH ranging from 3.5 to 4.0, produced a pleasant sweet-sour smell, appeared yellowish-brown, and was to be utilized within a two-week period. Conducting a pH test on every microbiological test was essential before treating the lake.

This was carried out to ensure that the pH remained within the required range. If the pH level was not within the appropriate range, the EM had to be re-prepared before being used to treat the lake. A lake water sample was taken at each point using water sampling tools, and the sample was put in a 5-L bottle. Different dosages of EMAS were used (5 mL, 10 mL, and 20 mL) with 1 litre sample of lake in a beaker. Each lake sample, together with its corresponding dosage, was preserved for a duration of five days. The water sample was tested using seven parameters: pH, TSS, BOD, CO, DO, $NH_3$-N, and Turbidity, before and after the dosage was added.

### *2.2. TeMo Decomposer (TeMo)*

EM was prepared by adding 500 g of brown sugar into 2 pieces of 'tempeh' and 6 L of tap water that was added into the mixtures. Tempeh needed to be chopped into small pieces before being addedto the mixture. The mixtures were then transferred into a clean, airtight container to avoid exposure to sunlight at ambient temperature for 7 days. TeMo Decomposer developed fungus on the surface of the solution. It was crucial for the pH level of TeMo to be maintained within the range of 5 to 6. If the pH level was not within the appropriate range, the effective microorganisms had to be re-prepared before being used to treat the lake. A lake water sample was taken at each point using water sampling tools, and the sample was put in a 5-L bottle. Different dosages of TeMo were used (5 mL, 10 mL, and 20 mL) with 1 L sample of lake in a beaker. Each lake sample with dosage was preserved for 5 days. The water sample was tested using seven parameters: pH, TSS, BOD, CO, DO, $NH_3$-N, and Turbidity, before and after the dosage was added.

### *2.3. Lactic Acid Bacteria (LAB)*

Lactic acid bacteria were part of the autochthonous microbiota of milk. Naturally found in milk products and decomposing plants, they produced lactic acid as the main metabolic end product [3]. Optimum growth temperatures of LAB ranged from 30–45 °C. EM LAB was prepared by using UHT milk. Two layers of milk formed after a week, and the pH should have been between 5 and 6 after 7 days of fermentation. A lake water sample was taken at each point using water sampling tools, and the sample was put in a 5-L bottle. Different dosages of LAB were used (5 mL, 10 mL, and 20 mL) with 1 L sample of lake in a beaker. Each lake sample, together with its corresponding dosage, was preserved for a duration of five days. The water sample was tested using seven parameters: pH, TSS, BOD, CO, DO, $NH_3$-N, and Turbidity, before and after the dosage was added.

## 3. Results and Discussion

### *3.1. Bacteria and Fungus Identification*

The microscopic inspection of cells using the Gram staining approach indicated the presence of Gram-positive cells. Gram-positive cells maintained the purple colour of the original stain. Bacterial morphology indicated that it lacked spores and exhibited both cocci and rod forms when viewed under a microscope. Lactic acid bacteria are a group of Gram-positive bacteria that are incapable of producing spores and could be either cocci or rod-shaped. They were unable to produce catalase and were demanding in their nutritional requirements, with a strong ability to survive in acidic environments. Lactic acid bacteria were present in dairy products, fermented foods like ‘tempeh’, and EMAS solution. Introducing LAB cultures to the lake could break down organic molecules, decreasing the risk of eutrophication and algae blooms.

The fungus that had been discovered in EMAS and TeMo could be identified as shown in Figure 1. As stated by Laconi and Astuti [4], ‘tempeh’ was a local food that was produced through the fermentation of soybeans with the help of *Rhizopus* sp. According to Laconi [5], fermentation with the fungus *Aspergillus niger* was required in order to improve the product’s quality by increasing the amount of protein and decreasing the amount of fibre. The use of *Aspergillus niger* in the fermentation process of solid tempeh waste had been demonstrated [5]. Under the microscope, *Aspergillus niger* and *Aspergillus flavus* were frequently discovered in EMAS. *Aspergillus niger* was capable of removing contaminants from wastewater while *Aspergillus flavus* functioned as a bio-coagulant, which was particularly useful for the removal of micro-algae from wastewater which shown in Figure 2.

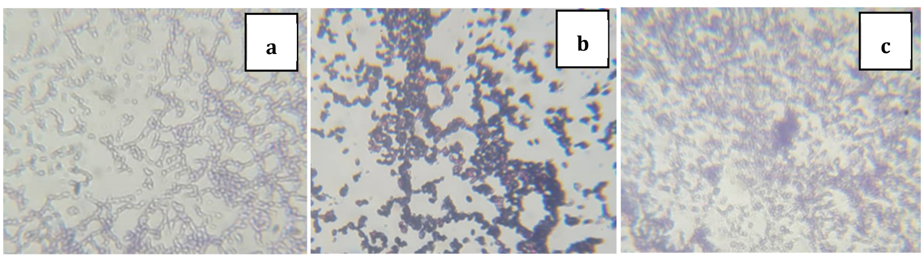


**Figure 1.** Bacteria identification for each EM under light microscope magnificent 40X, (**a**) Lactic acid bacteria in EMAS; (**b**) Lactic acid bacteria in TeMo, and; (**c**) Lactic acid bacteria in milk.

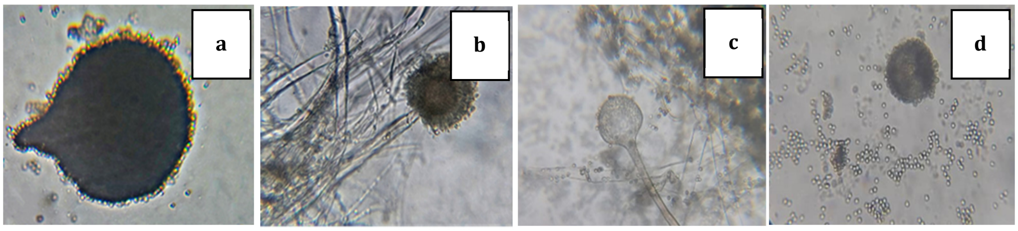


**Figure 2.** Fungal identification for EMAS and TeMo under light microscope magnificent 40X, (**a**) Conidiophore head of *Aspergillus niger* in EMAS; (**b**) Conidiophore head of *Aspergillus flavus* in EMAS; (**c**) Conidiophore head of *Rhizopus* sp. in TeMo and; (**d**) Conidiophore head of *Aspergillus niger* in TeMo.

### *3.2. Lake Water Treatment Results*

Figure 3 displayed the EM at their optimum dosage, which was 5 mL. For the initial data, point 1 had a Water Quality Index (WQI) of 87.1, point 2 had 86.16, point 3 had 81.35, and point 4 had 87.62. The results indicated that almost all points fell within class II. Table 1 displays the results from Point 1 to Point 4 after treatment with three different forms of EM at varied doses. Most of the WQI values fell within class II, except for point 3, where many data points were in class III. The colour of the EM did not have a direct influence on its effectiveness, however, it may reflect the microbial composition and activity.

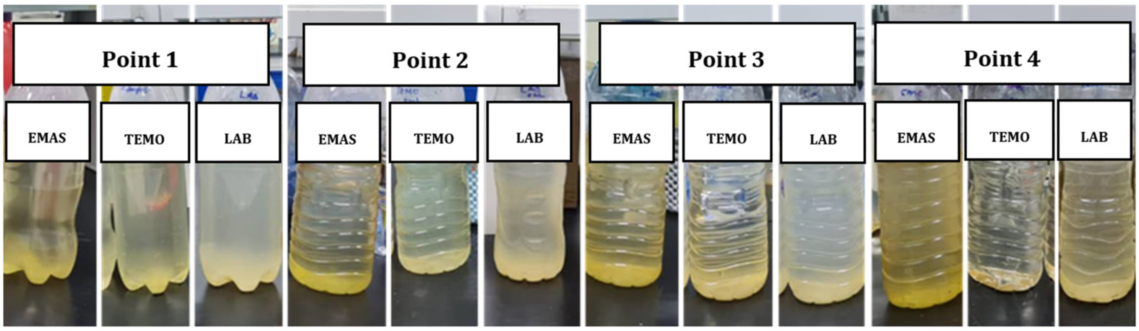


**Figure 3.** EM at 5 mL dosage.

**Table 1.** After Treatment Results for Each Point.

| **Type of EM & Dosages (mL)** | **EMAS** | | | **TeMo** | | | **LAB** | | |
|---|---|---|---|---|---|---|---|---|---|
| | **5** | **10** | **20** | **5** | **10** | **20** | **5** | **10** | **20** |
| After Treatment results at Point 1 | | | | | | | | | |
| WQI<br>Class | 90.79<br>II | 88.18<br>II | 86.40<br>II | 92.86<br>II | 90.54<br>II | 90.22<br>II | 83.9<br>II | 82.18<br>II | 80.67<br>II |
| After Treatment results at Point 2 | | | | | | | | | |
| WQI<br>Class | 89.83<br>II | 87.57<br>II | 87.51<br>II | 87.76<br>II | 87.13<br>II | 84.55<br>II | 81.63<br>II | 79.9<br>II | 77.47<br>II |
| After Treatment results at Point 3 | | | | | | | | | |
| WQI<br>Class | 84.44<br>II | 82.3<br>II | 81.52<br>II | 83.34<br>II | 81.18<br>II | 80.68<br>II | 78.52<br>II | 76.43<br>III | 73.35<br>III |
| After Treatment results at Point 4 | | | | | | | | | |
| WQI<br>Class | 91.41<br>II | 88.99<br>II | 88.97<br>II | 88.4<br>II | 87.34<br>II | 86.65<br>II | 83.87<br>II | 83.3<br>II | 82.64<br>II |

### *3.3. pH*

EMAS demonstrated an excellent outcome, particularly at a 5 mL dosage, based on the pH result. TeMo yielded similar positive results to EMAS, except for LAB, which exhibited a decrease in pH, becoming slightly acidic. Moreover, a 20 mL dosage resulted in a decrease in pH value, indicating a potential risk of overdosing when used for treating the lake. Using small dosages of fungi may have been more beneficial than using large doses when treating a lake [6]. Fungi could proliferate in the water, enhancing their biomass and capacity to eliminate pollutants as they expand.

Using excessive dosages of fungi can lead to unintended environmental consequences, such as imbalanced microbial activity. Utilizing reduced doses could perhaps have allowed the desired outcomes to be reached without unintentionally causing damage to the environment or other creatures [6]. The efficacy of EMAS and TeMo in raising pH levels may have been attributed to the bacteria and fungi present in the solution.

### *3.4. Dissolved Oxygen*

The results indicated in Figure 4 show that EM assistance contributed to raising DO levels in Tasik Alumni. Figure 4 shows the DO value after treatment at a 5 mL dosage. *Aspergillus flavus* in EMAS enhanced DO levels in lake water by decreasing contaminants through biosorption [7]. The low DO levels observed with LAB could be attributed to its anaerobic nature, which limits its oxygen consumption. Fungi could impact the concentration of DO in lakes through their interactions with other species and environmental conditions. They also contributed to the breakdown of organic substances, like deceased flora and fauna, which could influence oxygen concentrations. Fungi consumed oxygen during the decomposition of organic material, potentially decreasing DO levels and engaging with bacteria in water, impacting the oxygen requirements of the microbial community.

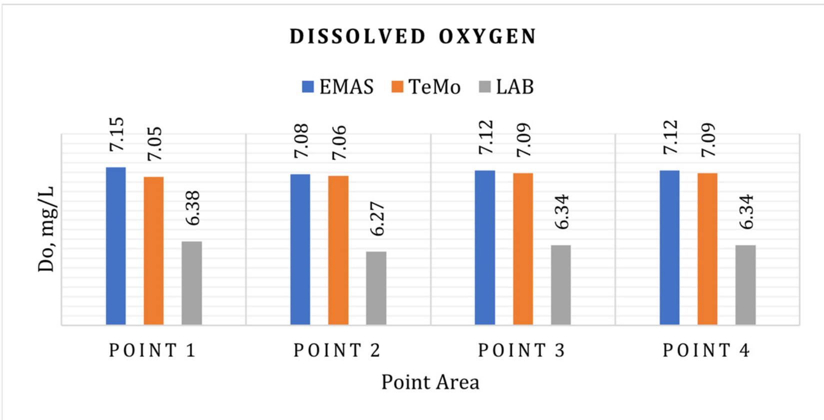


**Figure 4.** Dissolved Oxygen (DO) after treatment at 5 mL dosage.

Fungi used oxygen during decomposition, but their involvement in nutrient cycling and interactions with other organisms might have impacted the oxygen dynamics in lake ecosystems. EM was used to break down organic materials and pollutants in water into less or non-toxic chemicals. The elevated levels of pollutants acted as a substrate and provided nutrients for the growth and reproduction of bacteria.

### *3.5. Biochemical Oxygen Demand (BOD)*

The BOD value increased in the lake, particularly at point 3, due to the presence of organic waste such as leaves, dead plants, and wastewater from sources like cafeterias. These sources introduced organic matter into the water, which was then decomposed by microorganisms, leading to the consumption of DO. High BOD levels could lead to a drop in DO levels in water, making it crucial to monitor BOD levels in lakes. Therefore, the results indicated that EMAS could decrease the total BOD in Tasik Alumni by utilizing beneficial microbes like LAB, *Aspergillus niger*, and *Aspergillus flavus*. *Aspergillus niger* and *Aspergillus flavus* can reduce BOD in lakes by enzymatically degrading organic materials. Lactic acid bacteria in EMAS can significantly reduce BOD levels in Tasik Alumni, contributing to the maintenance of the aquatic ecosystem's equilibrium and the improvement of water quality [8].

Lactic acid bacteria have been researched for their possible applications in water treatment and bioremediation procedures. They could decompose organic material and oxygenate the water, aiding in regulating BOD levels and inhibiting the proliferation of detrimental algae and bacteria. Fungal degradation especially for *Aspergillus niger* and *Aspergillus flavus* naturally helped improve water quality by lowering BOD levels, which in turn benefited the health of aquatic organisms in lakes. *Aspergillus niger* produces enzymes like cellulases, amylases, and proteases, which help break down complex organic materials into simpler substances. These enzymes speed up the natural process of decomposing organic matter in water. Additionally, TeMo could decrease BOD levels at a 5 mL dosage, possibly due to the presence of *Rhizopus* sp., which aided in organic matter decomposition. *Rhizopus* sp. aided in the natural rehabilitation of lakes by breaking down organic molecules, hence reducing BOD levels and supporting the health of aquatic ecosystems. It was crucial to maintain adequate BOD levels to preserve the ecological balance and health of lakes.

### *3.6. Chemical Oxygen Demand (COD)*

The COD levels in points 1, 2, and 4 were lower than in point 3. Characteristics of water at these three points exhibited a slightly green colour in comparison to point 4. The elevated COD levels in a lake could be influenced by various variables, including the existence of organic contaminants. The organic contaminant found in soaps and detergents might have originated from the cafeteria and residential college. Fertilizers and pesticides could have impacted the levels of COD due to run-off. EM technology could decrease COD in a lake by utilizing beneficial microorganisms like bacteria and fungi. The photosynthetic bacteria in EM played a crucial role in collaborating with other microorganisms to decrease the presence of pathogenic microbes by creating specific chemicals that blocked and degraded harmful substances. Mandal et al. [9] stated that *Aspergillus niger* in EMAS and TeMo had the ability to create enzymes that broke down lignin and other phenolic compounds.

Different research discovered that *Aspergillus niger* had the potential to serve as an adsorbent for eliminating contaminants from contaminated lake water, particularly in Tasik Alumni [10]. *Aspergillus niger* and *Aspergillus flavus* were two fungal species investigated for their ability to decrease COD in wastewater, such as lake water. Furthermore, TeMo's efficiency in reducing the COD level was enhanced in the presence of *Rhizopus* sp. *Rhizopus* sp. at a concentration of 0.1 mL/L was shown to eliminate 54.09% of COD from wastewater [11]. *Rhizopus* sp. had the capacity to decrease COD levels in lake water.

### *3.7. Ammoniacal Nitrogen ($NH_3$-N)*

Ammonia in high amounts could be harmful to aquatic life, especially when the water's pH and temperature increase. $NH_3$-N in Tasik Alumni might have originated from diverse sources, including agricultural activity or residential colleges. Figure 5 shows the concentration of $NH_3$-N after treatment at 5 mL dosage. The 5 mL dosage was more effective in reducing $NH_3$-N for EMAS and TeMo, but not in LAB. This was because LAB in milk tended not to be suitable for reducing $NH_3$-N in a lake due to their primary use in fermentation processes and food production, rather than environmental remediation. *Rhizopus* sp. in TeMo was used in fermenting wastewater to eliminate nitrogenous chemicals like ammonia, aiding in reducing ammoniacal nitrogen in lakes. The utilization of *Rhizopus* sp. species in lake treatment could help enhance water quality by decreasing nitrogenous substances that cause eutrophication and damage aquatic habitats, particularly in Tasik Alumni. The combination of bacteria and fungi in EMAS may create an optimized environment for nitrogen reduction, working synergistically to break down $NH_3$-N more effectively than TeMo, which might contain fewer or less effective nitrogen-degrading species. The enhanced effectiveness of EMAS in reducing $NH_3$-N could be attributed to the presence of additional microbial species that are more efficient in nitrogenous compound degradation.

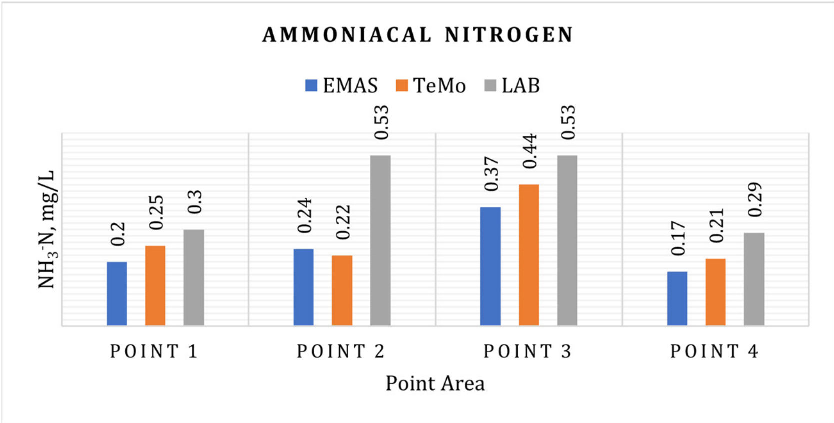


**Figure 5.** Concentration of Ammoniacal Nitrogen ($NH_3$-N) after treatment at 5 mL dosage.

### *3.8. Total Suspended Solid (TSS)*

The data indicated that the initial TSS values were higher at each point. Increased TSS levels could be attributed to soil erosion in nearby areas of Tasik Alumni. Additionally, it could have resulted from wastewater discharge, particularly from cafeterias and residential colleges that released wastewater daily through drains. Urban runoff, excessive algal growth, and disturbance of bottom sediment were other factors contributing to the elevated levels of TSS. Higher silt levels diminished water clarity, leading to less light penetration and thus limiting photosynthesis in aquatic plants. Water heated up faster and retained more heat. The decrease in TSS levels following the five-day treatment was particularly evident in EMAS due to the ability of EM to break down organic matter in the lake.

EMAShas been utilized as a method for lake restoration to enhance water quality and transparency. Research has shown that EMAS could help eliminate odours from lakes and regulate algal growth, leading to a reduction in TSS levels in water bodies [8]. EMAS included many helpful bacteria that could accelerate the breakdown of organic material in lakes. EMAS aided in the decomposition of organic substances, which supported the equilibrium of microbial ecosystems, promoted a conducive environment for aquatic organisms, and decreased TSS in the water.

### *3.9. Turbidity*

The rise in turbidity in lake water was mostly caused by suspended algae and soil erosion from the lake's shores. Dead organic waste and small floating organisms in the water might have increased turbidity in Tasik Alumni. Figure 6 shows the turbidity of Tasik Alumni after treatment at a 5 mL dosage. TeMo and EMAS effectively reduced turbidity values at every point in the lakes, as indicated by the results. *Aspergillus niger*, a species of fungus, showed promise in decreasing water turbidity. The decrease in turbidity from cloudier water to slightly clear was attributed to the presence of the fungus. Dosages of 5 mL and 10 mL could effectively reduce turbidity in lakes. *Aspergillus niger* had been discovered to produce enzymes that aided in the degradation of contaminants in water [12]. This fungus was frequently detected in TeMo and EMAS.

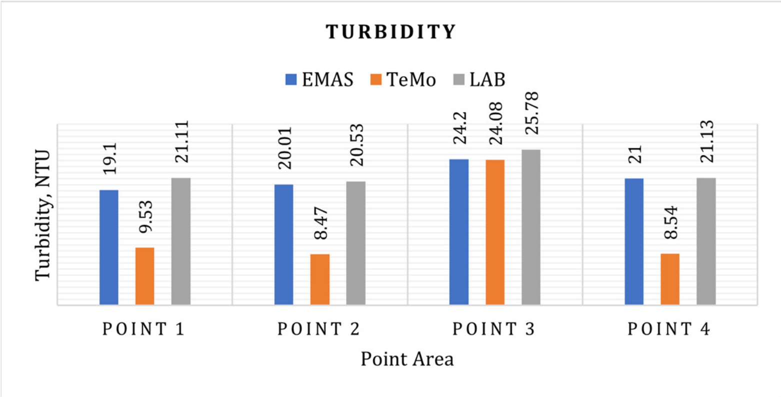


**Figure 6.** Turbidity after treatment at 5 mL dosage.

## 4. Conclusions

The findings suggested that EMAS was more successful in enhancing readings across all criteria. The 5 mL dosage was more effective than the 10 mL and 20 mL dosages. Bacterial and fungal presence enhanced the parameter readings. The study found that the majority of the bacteria and fungi identified were effective in eliminating a diverse range of pollutants. The consequences of overdose could be reduced by consuming small amounts of fungus. This was particularly important in environments where the impact of treatment could have a broader reach. Using lesser doses could help achieve desirable objectives without causing unintended harm to the environment or other organisms while still reaching the desired outcomes. The initial data for the WQI mainly belonged to class II. Following a five-day treatment, most of the data aligned with class I. Extending the treatment time further could lead to reaching class I status. Tasik Alumni could be classified as Class I according to the NWQS based on the post-treatment statistics.

The utilisation of EM technology yields significant conservation advantages by facilitating the rehabilitation of natural water bodies while minimising ecological disturbance. EMAS enables the sustainable enhancement of water quality in lake ecosystems by effectively controlling doses, hence promoting long-term health and conservation. The effective implementation of this technology highlights its potential as a vital instrument in environmental preservation efforts, guaranteeing that water bodies like Tasik Alumni attain and sustain optimal ecological conditions.

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