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# Photosynthetic Bacteria (PSB) as A Mechanism for Water Quality Improvement

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**Abstract**: Water contamination has been one of the most talked-about or discussed issues that put a severe burden on the environment since a long time ago, along with the limited availability of clean water. In conjunction with moving towards sustainable developments, an environmentally friendly and economical treatment technology is needed to overcome this issue. Hence, this research is intended to understand the characterization of Photosynthetic Bacteria (PSB) and the effectiveness of PSB towards water quality improvement. The experimental design was conducted as a batch process in a controlled environment. Four sets of different batch experiments at different types of sample preparation were prepared. The data collected in 12 days that conjunction with the pH, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Ammonia Nitrogen are utilized after the laboratory experiment. The result of BOD, COD and Ammonia Nitrogen before adding PSB is 11.5 mg/L, 23 mg/L and 4.31 mg/L respectively. When the presence of PSB showed the result of BOD, COD and Ammonia Nitrogen is 6 mg/L, 12 mg/L and 3.55 mg/L respectively. The percentage reduction of the BOD, COD and Ammonia Nitrogen when presence of the PSB was at 47.8%, 47.8% and 17.6% respectively. Thus, this research found that Photosynthetic Bacteria have the potency to lower the concentration of BOD, COD and Ammonia Nitrogen.

**Keywords**: Photosynthetic Bacteria, pH, BOD, COD, Ammonia Nitrate

## 1. Introduction

One of the most significant natural resources in the world is surface water. Water is essential for human existence [1]. The water of high quality has been specifically identified as a critical component of long-term social and economic development. It is providing the habitat for a wide range of species and this is an important aspect of animals and plants metabolism. A variety of contaminants, as well as harmful land-use or water management practices, could threaten the aquatic ecosystems on a global scale. Some of the issues have been prevalent for a long period but have just lately reached a critical level. The principal sources of fresh surface water are lakes and reservoirs. Lakes and reservoirs are important resources because they contain around 90% of the world's fresh surface water and serve as

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the primary freshwater resources for agriculture, fishery, residential and industrial [2]. From that, high levels of pollution can be found in streams and rivers either by point source or non-point source pollution. Basically, contaminant degrades the quality of water in lakes and other freshwater resources all over the world. Lakes frequently have excessive amounts of contaminants in comparison to the surrounding landscapes and environment. Pollution from the landscape is carried away by rivers and streams and concentrated in lakes and other bodies of water. This is because certain organic compounds do not dissolve or dilute in water and are instead taken in by organisms of the aquatic creatures such as fish that can be much polluted.

Toxic pollutants must be reduced or completely removed to reduce the hazard or risk to human health and the surrounding environment, which rely on water supplies on a daily basis. Generally, there have been many conventional techniques for remediation for instance reverse osmosis, ion exchange, chemical precipitation, adsorption and solvent extraction. However, according to Ali [3], these approaches required high capital investment and were time-consuming aside from having a high possibility of generating sludge disposal at the end of the remediation cycle. In conjunction with moving towards sustainable developments, an environmentally friendly and economical treatment technology is needed to overcome the issue of water that has been polluted with heavy metals contaminants. The implementation of the Photosynthetic Bacteria (PSB) technique is not only will benefit the environment but also be able to study the performances of the bacteria in eliminating the contaminants [4].

The aim of this research is to focus on the method to improve water quality by understanding the characterization of Photosynthetic Bacteria and studying the effectiveness of Photosynthetic Bacteria towards water quality. PSB is the oldest prokaryote on the planet that has a rudimentary photoenergy synthesis mechanism which is found in soil, streams, and seas [4]. Photosynthetic bacteria are being applied in a variety of applications such as water purification, bio-fertilizers, animal feed, and chemical bioremediation, among others [5]. To ensure the validation, the comparison between Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Ammonia Nitrate of data laboratory experiment was established. These relations were widely used to verify the effectiveness of Photosynthetic Bacteria as a mechanism for water quality improvement.

## 2. Photosynthetic Bacteria (PSB) Metabolism in Wastewater

Photosynthetic properties were discovered in purple bacteria, which demonstrated movement and growth when exposed to light [6]. Photosynthetic bacteria are a unique microorganism family that converts light energy into chemical energy via light absorption pigments and reaction centers. Bacteriochlorophyll is used by PSB to generate energy. Bacteriochlorophyll can absorb longer wavelengths of light than chlorophyll although chlorophyll and bacteriochlorophyll are remarkably similar [5]. However, Zhinan Xu [7] reported that the photosynthetic device of purple bacteria is basic, with just one photosystem (PS) which is fixed in the internal membrane and is not sufficient enough to separate the water.

PSB, unlike higher plants and algae, lacks chloroplasts and endothecium. The chromatophore, which contains a high concentration of Bchls and CDs on the inner folded cell membrane, is where photosynthesis occurs. In contrast to GPB and GFB, which only feature specialized structures known as chlorosomes that execute light-harvesting activities when exposed to light, PPB has a more complete ICM system for collecting light energy. Because of their distinct structural properties, they have extremely flexible material and energy metabolic pathways, which is the major reason for their extraordinary efficacy in wastewater purification.

Puyol [9] introduced an anaerobic mixed population phototrophic model that has the potential to be employed in the treatment of industrial wastewater. Furthermore, the key metabolic activities of PPB in household sewage were divided into five groups based on the assumptions made: photoheterotrophy on acetate, photoheterotrophy on other organics, chemoheterotrophy,

photoautotrophy, cell death, hydrolysis, and particle fermentation. However, several other energy storage patterns of PPB, such as $H_2$ production, poly-P and PHA buildup, were overlooked.

Light anaerobic, weak light-microaerobic and dark-aerobic conditions are characterized based on the quantity of light and oxygen available. The most prevalent and abundant metabolizer is PNSB. PNSB may adjust their metabolism to match the needs of the environment if there is adequate light and oxygen in the environment. The ratio of light and oxygen variables in the environment is crucial when it comes to the eventual prevailing metabolism. If the PNSB is exposed to a dark-aerobic environment, it will participate in aerobic respiration, generating energy via substrate-level phosphorylation and oxidative phosphorylation [10]. PNSB is capable of photosynthesis and fermentation when under the influence of light anaerobic conditions.

Instead of $O_2$, intermediate fermentation products are organic pollutants that have been partially mineralized as a result of the final electronic acceptors. PSB photosynthesize in response to light, utilizing sulphide, $H_2$ or tiny molecular organic materials in the wastewater as electron donors that will lower $CO_2$ to complete the biological growth. Then, the most remarkable aspect of PSB-based wastewater treatment is resource recovery through solid-liquid separation. As for the weak light-microaerobic state, it is closer to the real working circumstances since no extra light energy or significant aeration is required. Both the presence of light and the presence of $O_2$ emerge from a significant struggle between the two metabolic chains' direct superposition.

## 3. Materials and Methods

The research methodology starts with the study of literature review, followed by the sample preparation that will be used in this study, experimental process and data collection from a laboratory experiment as shown in Figure 1.

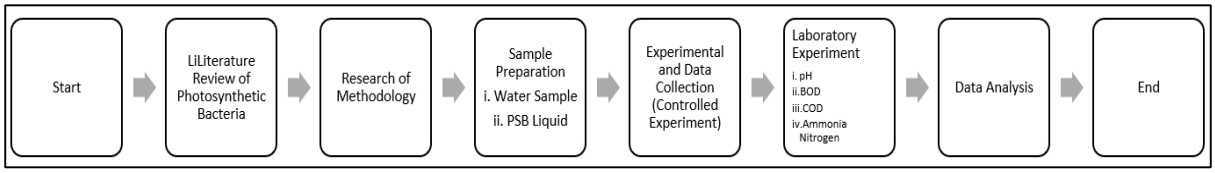


**Figure 1: Flow of this project**

### 3.1 Sample Preparation

This study requires a Photosynthetic Bacteria liquid and lake water sample in order to satisfy the objectives that have to be achieved at the end of the research. The research location is situated inside the campus of Universiti Tun Hussein Onn Malaysia, Johor, near the Faculty of Civil Engineering and Building Environment (1°50′″N, 103°05′04.4″; around 4.952m$^2$ area). The pond water was primarily supplied by rainfall, industrial and agricultural waste due to the location of the pond that was bordered by palm oil and industrial planting. The water sample has been collected 12 Liter in each box. The sample was collected from the site using communal equipment by decanting the water and filling it in a marked container. As a preservation precaution, contact with the sample containers is prevented by the collective device during the transfers. The samples are covered to keep dark. The sample was analyzed for water quality within 14 days from the sample collection date.

### 3.2 Experimental and Data Collection

The experiment was conducted as a controlled experiment. The experimental design was conducted as a batch process. A few sets such as 4 sets of different batch experiments at a different type of sample preparation using a large plastic storage box with a volume of 27.44 $cm^3$ (49 cm length x 32 cm width x 17.5 cm height) have been experimented as shown as the illustrated in Figure 2. According to the figure, the first box only consists of the lake water, the second box consists of the lake water and PSB, the third box contains the lake water, media and PSB and the fourth box consists of lake water, media, PSB and aeration.

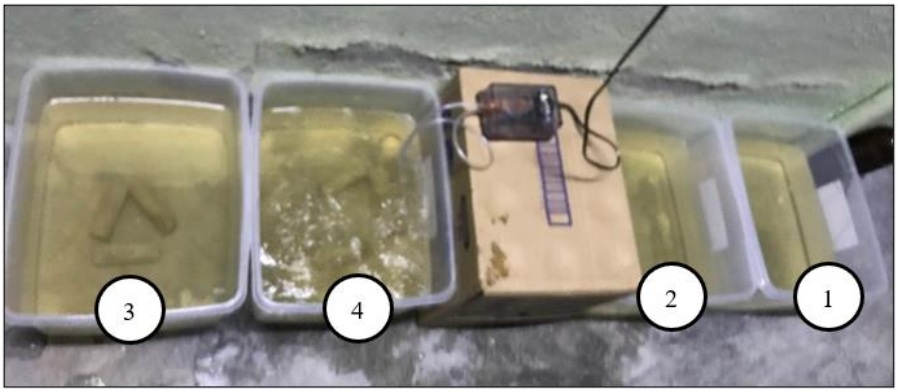


**Figure 2: The four sets of different batch experiments at a different type of sample preparation**

The media acted as the host of the photosynthetic bacteria. The media that has been used in this project is mineral ceramic bio ring filter media in a cylinder shape with sizes 4 cm in diameter and 16 cm in length. Three of the media were added in the box that labeled numbers three and four. Furthermore, aeration is part of the step known as the process of secondary therapy. In this project, NS L15 dual outlet air pump with 220V has been used that will be regularly circulated. Aeration supplies the microorganisms with oxygen for wastewater treatment and stabilization. The bacteria require oxygen to enable biodegradation. Lastly, 4 mL of Photosynthetic Bacteria liquid was added in box two, three and four using the syringe every day in order to study the effectiveness of Photosynthetic Bacteria.

### 3.3 Laboratory Experiment

The performance of the Photosynthetic Bacteria was assessed of its efficiency on the water contaminant. This research has been carried out as a laboratory experiment to record the water quality and utilize the data to evaluate the effectiveness of the PSB. The data collected in conjunction with the pH, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Ammonia Nitrogen are utilized at the conclusion of the experiment instruments based on the National Water Quality Standard (NWQS) for Malaysia were used to measure the water quality parameters as shown in Table 1.

**Table 1: Standard methods use for water quality parameters**

| Parameters | Standard Methods |
|---|---|
| pH | pH meter – electrodes millivoltmeter |
| Biological Oxygen Demand (BOD) | HACH: Method 8043 |
| Chemical Oxygen Demand (COD) | HACH: Method 8000 |
| Ammonia Nitrogen | HACH: Method 8038 |

After 3 days of the experimental sample that has been conducted, the laboratory experiment evaluated the potency of the Photosynthetic Bacteria towards water improvement. The sample from

each box has been tested 6 times on day 1, day 3, day 5, day 8, day 10 and day 12. Thus, from the laboratory test, the removal of organic pollutants from the UTHM's lake by implementing the Photosynthetic Bacteria can be determined and analyzed.

## 4. Results and Analysis

### 4.1 pH

Table 2 showed the result of the pH value for the 6 times experiment by implementing the Photosynthetic Bacteria (PSB), media, and aeration.

**Table 2: pH value**

| Day | Sample | | | |
|---|---|---|---|---|
| | **Box 1** | **Box 2** | **Box 3** | **Box 4** |
| 1 | 6.41 | 6.48 | 6.52 | 6.53 |
| 3 | 6.41 | 6.49 | 6.52 | 6.54 |
| 5 | 6.42 | 6.49 | 6.55 | 6.56 |
| 8 | 6.42 | 6.52 | 6.56 | 6.59 |
| 10 | 6.43 | 6.53 | 6.58 | 6.59 |
| 12 | 6.43 | 6.53 | 6.58 | 6.60 |

From the result, it is stated that the pH value increase as the days increase. For box 3 and box 4 showed a significant increase for having the media in those boxes as the final day stated the pH value is 6.58 and 6.60 respectively. It is still acidic but it is still showing the change of value pH when the presence of Photosynthetic Bacteria and mineral ceramic bio ring filter media from 6.41 pH. Mophin and Nair [11] had mentioned that media had the function of stabilizing the pH value. So, it is proved when there are changes in the value of pH in the implementation of PSB towards the lake water.

### 4.2 Biological Oxygen Demand (BOD)

Table 3 showed the result of the BOD value for 6 times experiment by implementing the Photosynthetic Bacteria (PSB), media, and aeration.

**Table 3: The concentration of BOD in mg/L**

| Day | Sample | | | |
|---|---|---|---|---|
| | **Box 1** | **Box 2** | **Box 3** | **Box 4** |
| 1 | 11.5 | 10.0 | 9.0 | 8.5 |
| 3 | 11.0 | 9.0 | 8.5 | 8.0 |
| 5 | 11.0 | 8.0 | 7.5 | 6.5 |
| 8 | 9.5 | 7.5 | 6.5 | 5.5 |
| 10 | 9.0 | 7.0 | 5.5 | 5.0 |
| 12 | 8.5 | 6.0 | 4.5 | 4.5 |

From the result, it is shown that a decrease in value in $BOD_5$ in mg/L as the days is increasing. For the box 2 displayed the value of 10 mg/L on day 1 and 6 mg/L on the last day of the experiment. Furthermore, in box 3 and box 4, the value of the $BOD_5$ expressed a similar result which was 4.5 mg/L on day 12. Thus, in this project, it is proved that the presence of Photosynthetic Bacteria can reduce the $BOD_5$ value. The biological oxygen demand (BOD) of water reflects the quantity of soluble organic matter present in the water. The BOD of water is thus a sign of its purity, while the BOD of contaminated water is an indicator of its contamination.

4.3 Chemical Oxygen Demand (COD)

Table 4 showed the result of the COD value for 6 times experiment by implementing the Photosynthetic Bacteria (PSB), media, and aeration.

**Table 4: The concentration of BOD in mg/L**

| Day | Sample | | | |
|---|---|---|---|---|
| | **Box 1** | **Box 2** | **Box 3** | **Box 4** |
| 1 | 23 | 20 | 18 | 17 |
| 3 | 22 | 18 | 17 | 16 |
| 5 | 22 | 16 | 15 | 13 |
| 8 | 19 | 15 | 13 | 7 |
| 10 | 18 | 14 | 11 | 8 |
| 12 | 17 | 12 | 9 | 9 |

From the result, it is shown that the decrease in COD value as the increasing of the day experiment. Box 2 and box 4 experienced in 8 mg/L reduction of COD value from 20 mg/L to 12 mg/L and 17 mg/L to 9 mg/L respectively. Meanwhile, the box 3 stated that 8 mg/L of COD value that is from 18 mg/L to 9 mg/L. Thus, it is proved that the presence of Photosynthetic Bacteria can reduce the COD value in water. Larger concentrations of COD indicate a greater quantity of oxidizable organic material in the sample that which will result in lower concentrations of dissolved oxygen (DO). A decrease in DO may result in anaerobic circumstances which are harmful to higher aquatic life forms.

4.4 Ammonia Nitrogen

Table 5 showed the result of the Ammonia Nitrogen value for 6 times experiment by implementing the Photosynthetic Bacteria (PSB), media, and aeration.

**Table 5: Ammonia Nitrate result in mg/L**

| Day | Sample | | | |
|---|---|---|---|---|
| | **Box 1** | **Box 2** | **Box 3** | **Box 4** |
| 1 | 4.31 | 3.80 | 3.65 | 3.65 |
| 3 | 4.29 | 3.69 | 3.64 | 3.64 |
| 5 | 4.29 | 3.64 | 3.62 | 3.63 |
| 8 | 4.28 | 3.58 | 3.59 | 3.60 |
| 10 | 4.28 | 3.57 | 3.58 | 3.58 |
| 12 | 4.27 | 3.55 | 3.56 | 3.57 |

From the result, it is stated that the Ammonia Nitrate value is decreasing as the increasing of day. Box 2, box 3 and box 4 showed the decreasing result as 3.55 mg/L, 3.56 mg/L and 3.57 mg/L respectively for day 12 of the experiment. Box 2 experienced in a larger reduction of NH3-N value which is 0.25 mg/L. Thus, it is proved that the presence of Photosynthetic Bacteria can reduce the Ammonia Nitrate value in water.

## 5. Discussion

The potential of Photosynthetic Bacteria as a technique for improving water quality has been shown in laboratory experiments. It may lower the concentrations of Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Ammonia Nitrate. Figure 2 showed the bar chart that represents the percentage of reduction in the concentration of the BOD, COD and Ammonia Nitrogen when the presence of Photosynthetic Bacteria is in box 2, box 3 and box 4.

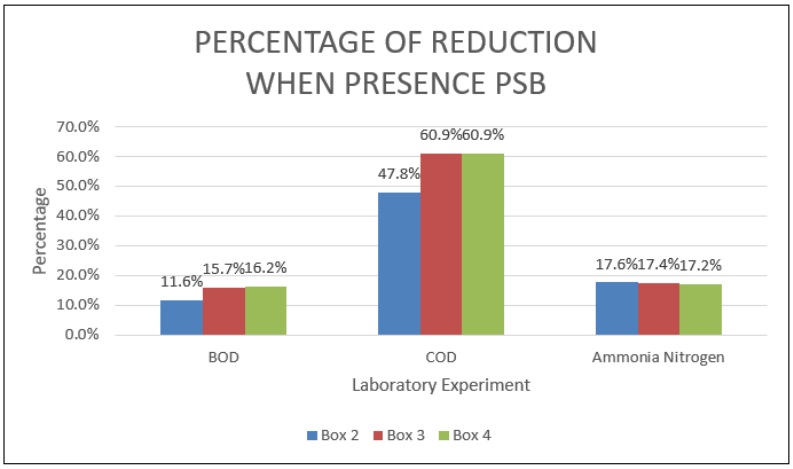


**Figure 2: Percentage of Bar Chart of reduction the concentration BOD, COD and Ammonia Nitrogen**

The bar chart represents the reduction of the concentration of BOD, COD and Ammonia Nitrogen in box 2, box 3 and box 4 when implementing the PSB, media and aeration. The result of BOD is showed that box 4 has the highest reduction with 16.2% when the presence of PSB, media and aeration compared to box 2 and box 3 which is 11.6% and 15.7% respectively. Next, box 3 and box 4 showed the higher percentage reduction of the concentration COD at 60.9% which is closed to the reduction of the concentration COD in box 2 accounting for 47.8%. For the result of Ammonia Nitrogen, it is shown that the reduction of Ammonia Nitrogen in box 2, box 3 and box 4 are quite similar at 17.6%, 17.4% and 17.2% respectively. Thus, it is proved that supplementing with PSB might lower the concentrations of BOD, COD and Ammonia Nitrate.

Furthermore, aside from lowering the concentrations of BOD, COD, and Ammonia Nitrate, the presence of Photosynthetic Bacteria (PSB) works as a colour enhancer after day 12, as shown in the Figure 3. It is having the capacity to improve the environment by cleaning and purifying water such as $H_2S$ accumulated on the bottom of the box.

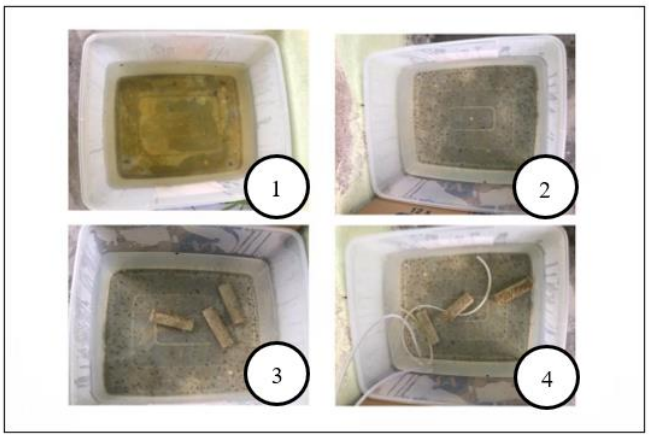


**Figure 3: Colour enhance when the presence of Photosynthetic Bacteria**

Photosynthetic Bacteria contain special active bacteria that can decompose toxic matter such as organic matter, hydrogen sulfide, nitric acid, ammonia and sludge to improve water quality in the lake. If rainwater contains acids flow, the lake is easily contaminated by acid rain. Therefore, PSB could clarify and purify water quality and increase the oxygen capacity in water. Furthermore, Photosynthetic Bacteria used to maintain water quality and soil quality in lakes under the sun that PSB will undergo the process of photosynthesis to grow. PSB is harmless to aquatic animals and requires very little oxygen. Therefore, PSB will not cause insufficient oxygen in the lake.

## 6. Conclusion

In a nutshell, the objective of this project has been achieved which is to understand the characterization of PSB and to study the effectiveness of PSB towards water quality. PSB system has high removal effectiveness of BOD, COD and Ammonia Nitrogen in high concentration organic wastewater when used to treat lake water as the result showed the percentage of reduction the COD, BOD and Ammonia Nitrogen when the presence of PSB is 11.6%, 47.8% and 17.6% respectively. PSB's characteristics include ease of start-up, a short incubation and domestication time, stable operation under high organic loading and organic wastewater treatment at high concentration without dilution as shown in experimental studies. Photosynthetic Bacteria is one of the based technologies that are a potential alternative to meet sustainable wastewater treatment requirements. In this study, the improvement of water quality as it changes the microbial community structure can be determined whereas the Photosynthetic Bacteria would be able to act as the agent of water treatment.

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