Using Duckweed to Improve the Water Quality

Zuraini Din
Kolej Komuniti Bandar Penawar, Johor
zuraini@kkbpenawar.edu.my

Norrizah Abd Wahab
Politeknik Sultan Haji Ahmad Shah, Pahang
norrizah@polisas.edu.my

Siti Norzailina Md Som
Politeknik Sultan Idris Shah, Selangor
norzailina@psis.edu.my

Abstract
Water plays an important role in everyday life. Water is vital to our health, communities and economy. Rapid industrial development and population growth contribute to water pollution The purpose of this research is to study the impact of aquatic plants in purifying the river and lake water. The aquatic plant used is duckweed which is easily found in the irrigation system in Malaysia. The importance of this study is to find an environmentally friendly method in purifying water. The study was conducted in two stages; the first stage was breeding the duckweed on the surface of water samples. The test was conducted in a laboratory and the water samples are in a stagnant condition. The second stage was conducting the laboratory test on water quality. Test parameters are Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), color and turbidity. The BOD result is improved to 3 mg/l and from Class IV to Class II. The biological activity of the biofilm from algae and bacteria that stick to the plant stems and roots has improved the BOD. After treatment, the COD result is improved to 11.75 mg/l but still in the same Class which is in Class IIA. COD is higher than the BOD because more elements can be biologically oxidized than chemically oxidized. Although no significant change for color and turbidity of water after the treatment process. As a conclusion duckweed can improve the physical properties of water and has a high potential in improving the water quality naturally. The limitation of this study is the duckweed is done in the laboratory where the water is in a stagnant condition. These as a result show that duckweed can improve the water quality for lakes or ponds.

Keywords: Duckweed, pollution, water quality

1.0 Introduction

Water plays an important role in everyday life. Water is vital to our health, communities and economy. In Malaysia most of the portable water is from the rivers and the main source of river water came from the rain. Rainwater is relatively clean and pure water that needs minor treatment and can be used for many applications such as; irrigation, domestic and industrial uses. Demand for water supply is growing in line with population growth and the development of the economic sector. Water production and consumption recorded in 2019 were 17,763 million liter per day (MLD) and 11,540 MLD respectively (DOSM, 2020)

Rising in food, housing and energy demand of increasing population creates an immense pressure on water resources, especially on water quality. The water quality around the globe is degrading primarily due to intense agricultural activities associated with rapid urbanization (Giri & Oiu, 2016). Good water quality is essential for all living things. In the March 2019 incident, residents near the Sungai Kim Kim, including students, suffered breathing difficulties, nausea and fainting due to the pollution (NST 2021). The pollution has affected more than 2,000 people and caused 114 schools in Pasir Gudang ordered to be closed (Yap, 2019).

Rapid industrial development and population growth contribute to water pollution. Due to urbanization and modernization, river water pollution is a severe problem in Malaysia and has an adverse impact on the sustainability of water resources (Afroz & Rahman, 2017). Malaysia government has taken many measures to control the quality of domestic water pollution for centuries. Quality of water resources also concerns the relevant authorities. Legislation is available in the form of Environmental Quality Act (EQA) 1974, which deals mainly with point source pollutants from the domestic and industrial sources. 53% of the river's water quality in Malaysia was categorized as slightly polluted or polluted (Goi, 2020). In developing countries, water treatment facilities have progressed tremendously. However, water treatment costs would be high if the water qualities are low and inconsistent.

The purpose of this research is to study the impact of aquatic plants in purifying the river and lake water. The aquatic plant used is duckweed which is easily found in the irrigation system in Malaysia. The importance of this study is to find an environmentally friendly method in purifying water. The study was conducted in two stages. The first stage was breeding the duckweed on the surface of water samples. The test was conducted in a laboratory and the water samples are in a stagnant condition. The second stage was conducting the laboratory test on water quality. Test parameters are Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), color and turbidity.

2.0 Literature Review

Malaysia's population in 2021 is estimated at 32.7 million as compared to 32.6 million in 2020 with an annual growth rate of 0.2 per cent (DOS, 2021). Rapid urbanisation and population growth have contributed both to an ever-increasing demand for water consumption and, at the same time, to the level of water pollution in Malaysia (Nor Azura, 2021). The major pollutants in Malaysia rivers and lakes are Biochemical Oxygen Demand (BOD), Ammoniacal Nitrogen (NH_3-N) and Suspended Solids (SS) (Huang, 2015). High in BOD can be contributed to inadequate treatment of sewage effluent from agriculturally based and manufacturing industries. The main sources of NH_3-N were animal farming and domestic sewage. While the sources for SS were mainly due to improper earthwork and land cleaning activities. The Department of Environment (DOE) uses Water Quality Index (WQI) to indicate the level of pollution as shown in Table 1. Table 2 illustrate the corresponding suitability in terms of water uses according to the National Water Quality Standard for Malaysia (NWQS).

Table 1: National water quality standards for Malaysia-DOE water quality **i**ndex classification

Parameter	Unit	Class					
		I	IIA	IIB	III	IV	V
Ammoniacal Nitrogen	mg/l	0.1	0.3	0.3	0.9	2.7	> 2.7
Biochemical Oxygen Demand	mg/l	1	3	3	6	12	> 12
Chemical Oxygen Demand	mg/l	10	25	25	50	100	> 100
Dissolved Oxygen	mg/l	7	5-7	5-7	3-5	< 3	< 1
pH	-	6.5-8.5	6-9	6-9	5-9	5-9	-
Colour	TCU	15	150	150	-	-	-
Electrical Conductivity*	µS/cm	1000	1000	-	-	6000	-
Floatables	-	N	N	N	-	-	-
Odour	-	N	N	N	-	-	-
Salinity	ppt	0.5	1	-	-	2	-
Taste	-	N	N	N	-	-	-
Total Dissolved Solid	mg/l	500	1000	-	-	4000	-
Total Suspended Solid	mg/l	25	50	50	150	300	300
Temperature	^oC	-	Normal + 2 ^oC	-	Normal + 2 ^oC	-	-
Turbidity	NTU	5	50	50	-	-	-
Faecal Coliform**	count /100ml	10	100	400	5000 (20000) *	5000 (20000) *	-
Total Coliform	count /100ml	100	5000	5000	50000	50000	>50000

Notes:
N : No visible floatable materials or debris, no objectional odor or no objectional taste.
* : Related parameters, only one recommended for use
** : Geometric mean
a : Maximum not to be exceeded

Table 2: Water classes and uses

Class	Uses
Class I	Conservation of natural environment. Water Supply I – Practically no treatment necessary. Fishery I – Very sensitive aquatic species.
Class IIA	Water Supply II – Conventional treatment required. Fishery II – Sensitive aquatic species.
Class IIB	Recreational use with body contact.
Class III	Water Supply III – Extensive treatment required. Fishery III – Common, of economic value and tolerant species; livestock drinking.
Class IV	Irrigation
Class V	None of the above.

According to the researcher, the duckweed and azolla which are considered invasive weeds can play an important role in biofiltration and water quality remediation in aquarium stocked with the fantail goldfish. These two plants also serve as additional feed ingredients for the fish. It is a sort of biological pruning of the plants. The experimental results revealed that the feed efficiency was better with the duckweed compared to azolla. The duckweed supported better growth performance of the fantail goldfish. The combination of fish and aquatic plants in an aquaculture system is cost-effective, resource-efficient, and environment-friendly (Mohd Roslan, 2021).

Studies are also conducted on other aquatic plant. The researcher uses water hyacinth (*Eichhornia crassipes*) was used to treat domestic wastewater. Ten organic and inorganic parameters were monitored in three weeks for water purification. It reveals that the optimum growth rate of water hyacinth has great effect on waste water purification efficiency in continuous system and nutrient removal was successfully achieved (Rezania, 2016).

2.1 Duckweed

Duckweed is a macrophyte species, as shown in Figure 1. Much research has been conducted in relation to water treatment using duckweed. Duckweed-based wastewater treatment systems with low-cost, simple infrastructure offer real solutions to urban and rural waste management problems (Yu, 2014).

Duckweed is a free-floating aquatic plant that is small and delicate. It grows only 1millimeter deep to a water depth of sometimes 3 meters on mud or water. If the nutrient density is optimal, their vegetative reproduction works quickly. However, when nutrient deficiency or major nutrient imbalance occurs, their growth acts slowly. They are opportunistic in their use of nutrient flushes and may set growth spurts during such periods. Duckweeds belong to five genera namely Lemna, Landoltia, Spirodela, Wolfia and Wolffiella. From the researches, about 37 species of duckweed are known worldwide. These species have a simple structure with no obvious stems or leaves. All species have flattened, tiny, like oval to round fronds from about 1 mm to less than 1 cm in diameter (Yu Liu et al, 2020).

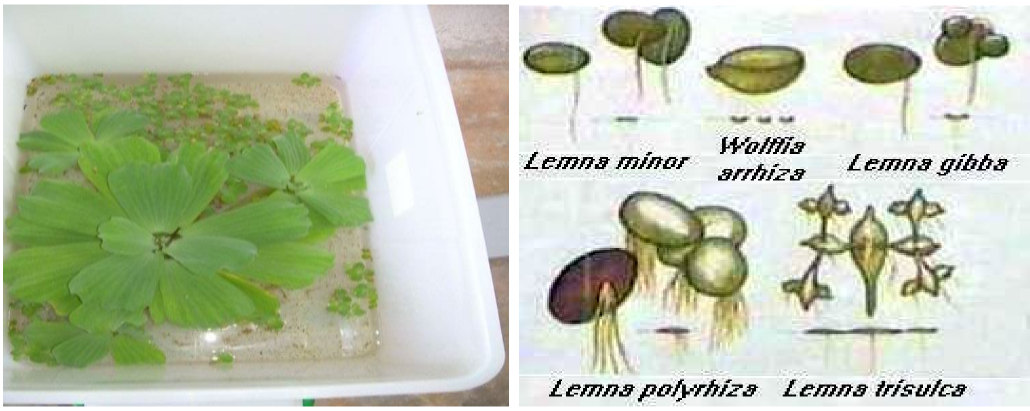

Figure 1: Duckweed

Under ideal conditions, such as a good pH, adequate water temperature and sunlight, a complete supply of nutrients, it will definitely contribute to the production of biomass with the highest photosynthesis of terrestrial plants. It will double the process of biomass production in a period of 16 to 48 hours, depending on the situation (Paul, 2014). Based on the calculated technique, this shows that the growth of duckweed is not limited even in an area of 10 cm2. Therefore, it can grow up to 100 million cm^2 in just 1 hectare. This process takes only 50 days (Muradov, 2014).

Duckweed is not only a landscape crop, but serves as an ecosystem. Its roots can provide nutrients to aquatic species and the broad leaves also benefit aquatic species. In Malaysian irrigation, duckweed can live and grow easily, but this plant needs to be maintained to prevent its growth covering the water surface. In Malaysia, duckweed is also widely used in aquariums.

3.0 Methodology

The study was conducted on an unnamed river that flows behind the Politeknik Sultan Haji Ahmad Shah, Kuantan Pahang (POLISAS) staff quarters block as shown in Figure 2 below. This river channel has a width of approximately 2 m and the length of the river is 850 m from the starting point of the POLISAS to Taman Maktab Perguruan Tengku Ampuan Afzan.

Figure 2: Study area – River where the effluent is release

Sampling stations in the study area were taken at two stations; the first station (A) is 100 meters from the effluent outlet and the second station (B), 100 meters from station A. The determination of the two stations as sampling points is because along the river from POLISAS to Taman Maktab Perguruan Tengku Ampuan Afzan, there is no changes in human activities carried out along the river and along the river there are only forests. Referring to previous studies, researchers determined sampling stations based on different activities along the river (Alfarooq Basheer, 2017).

Samples were taken in the morning at 8 am. The purpose of the samples taken in the morning is to get the data matching the conditions sewage entering the plant. Water samples were taken using the grab sampling method or known as water sampling by hand. This method is suitable for the condition of the river which is not too deep and not too wide (AWWA. 2005). Table 3 shows the sampling and handling requirement of water samples.

Table 3: Sampling and handling requirement

Determination	Container +	Minimum Sample Size mL	Sample Type++	Remark
BOD	P, G	1000	g, c	Refrigerate
COD	P, G	100	g, c	Analyze as soon refrigerate
Color	P, G	500	g, c	Refrigerate
Turbidity	P, G	100	g, c	Analyze same refrigerate

+ P = plastic (polyethylene or equivalent); G = glass; G(A) or P(A) = rinsed with 1 + 1 HNO3; G(B) = glass, borosilicate; G(S) = glass, rinsed with organic solvents or baked.
++ g = grab; c = composite.
* Refrigerate = storage at 4°C ± 2°C; in the dark; analyze immediately = analyze usually within 15 min of sample collection.

Source: AWWA (2005)

Two samples of water are taken at each station, Station A and Station B. The water sample is inserted in 2 tanks up to 30 cm depth of water because the original habitat of this plant is between 10 cm to 30 cm and the tank size is 90 x 60 cm. The tank was placed at POLISAS Environmental Laboratory close to the window for natural lighting. Duckweed was placed on the 1/3 of sampling water surface and retention time was 21 days before the water was tested.

Only four parameters are tested due to limited facilities. The water quality parameters of COD and BOD are done in an external laboratory. Turbidity and color parameters are done in the Environmental Laboratory, POLISAS.

4.0 Results and Discussions

Experiments on water samples were done before and after water samples were treated using duckweed. The results obtained from the above experiments are analyzed by making a comparison with the Water Quality Index (WQI) refer to Table 1 and Table 2.

4.1 Biochemical Oxygen Demand (BOD)

Biochemical Oxygen Demand (BOD) is to measure the quantity of oxygen required by microorganisms to oxidize organic matter in aerated conditions. BOD parameter tests were performed for knowing the quantity of oxygen used during the decomposition reaction of organic matter that takes place naturally. Referring to DOE, the BOD value of clean river water is supposed to be at a value of less than 1 mg/l. The BOD result is shown in Table 4.

Table 4: BOD result (mg/l)

Treatment	Station A			Station B			Class
	Sample 1	Sample 2	Average	Sample 1	Sample 2	Average	
6.0Before	8	9	8.5	8	8.5	8.25	IV
After	2	4	3	2	3.5	2.75	IIA

The highest BOD value is 8.5 mg/l at Station A before the treatment process and the lowest BOD value is 2.75 mg/l at Station B after the treatment process. The results after treatment show that the duckweed improves the water quality for BOD parameters which is from Class IV to Class IIA. The percentage of improved BOD quality is 64.7%.

4.2 Chemical Oxygen Demand (COD)

The Chemical Oxygen Demand (COD) parameter is commonly used to measure water polluted by a chemical due to human activity, and it can be defined as the amount of oxygen that is required for the oxidation of a compound substance. The analysis showed the values of COD parameters as referred to in Table 5.

Table 5: COD result (mg/l)

Treatment	Station A			Station B			Class
	Sample 1	Sample 2	Average	Sample 1	Sample 2	Average	
Before	17	18	17.5	18	16	17	IIA
After	12	13	12.5	11.5	12	11.75	IIA

The highest COD value was 17.5 mg/l recorded at Station A before the water underwent the treatment process. The lowest COD value was

11.75 mg/l at Station B after the treatment process. The results of the COD experiment showed that the water class did not change where it remained in class IIA. Yet the use of Duckweed has shown a slight improvement in the quality of COD parameters. After treatment, Station A recorded a slight improvement in quality from 17.5 mg/l to 12.5 mg/l. For Station B also showed similar results, quality improvement from 17 mg/l to 11.75 mg/l.

4.3 Color

The color of the water can be defined as the degree of energy absorption in the spectra of light in vision between wavelengths of 400-700nm (nanometers). It is expressed in unit CU. Table 6 shows the color values for water samples before and after the treatment process.

Table 6: Color result (TCU)

Treatment	Station A			Station B			Class
	Sample 1	Sample 2	Average	Sample 1	Sample 2	Average	
Before	0.37	0.30	0.34	0.35	0.29	0.32	II
After	0.24	0.25	0.245	0.20	0.19	0.195	

The highest result is at Station A with 0.34 TCU, before the treatment process. After the treatment, Station B gave the lowest value with 0.195 TCU. Although it is not a significant change, the result shows there are some improvements in water quality. Both the water color test results placed it in Class I.

4.4 Turbidity

Turbidity is one of the physical characteristics of water clarity. Water will appear cloudy, murky or otherwise colored affecting the physical look of the water. Turbidity is caused by particles of clay and silt, and based on the amount of light scattered by the particle in the water. Turbidity is expressed in unit NTU as shown in Table 7. There were no significant changes on the turbidity before and after treatment and the test results placed it in Class I.

Table 7: Turbidity Result (NTU)

Treatment	Station A			Station B			Class
	Sample 1	Sample 2	Average	Sample 1	Sample 2	Average	
Before	0.27	0.28	0.275	0.26	0.29	0.275	II
After	0.23	0.25	0.240	0.24	0.23	0.235	

4.5 Discussion

After treatment, the BOD result is improved to 3 mg/l and from Class IV to Class II. The biological activity of the biofilm from algae and bacteria that stick to the plant stems and roots has improved the BOD. After treatment, the COD result is improved to 11.75 mg/l but still in the same Class which is in Class IIA. COD is higher than the BOD because more elements can be biologically oxidized than chemically oxidized.

Although no significant change for color and turbidity of water after the treatment process. Color and turbidity are related with organisms that live and suspended solids in the water.

5.0 Conclusions

The water quality parameters in the research guided to the four parameters of the Water Quality Index (WQI). Overall, the results of the analysis indicate that duckweed is proven to improve the water quality and clarity of the water. The water quality parameter on BOD, show an improvement of water quality where the duckweed is improving the water class from class IV to IIA. As for turbidity, color and COD although the results show that the water class did not change where it remained in in the same but the Duckweed has shown a slight improvement in the quality.

As a conclusion duckweed can improve the physical properties of water and has a high potential in improving the water quality naturally. The limitation of this study is the duckweed is done in the laboratory where the water is in a stagnant condition. These as a result show that duckweed can improve the water quality for lakes or ponds. For rivers, more research needs to be carried out.

Acknowledgment

The author gratefully acknowledges the Civil Engineering Department POLISAS for giving the permission to use the Environmental Laboratory to carry out the experiment successfully.

References

Afroz R., Rahman A. (2017). Health impact of river water pollution in Malaysia. *Int. J.Adv.Appl. Sci.* 2017;4(5):78–85.

AWWA. 2005. *"Method for the Examination of Water and Wastewater".* USA

Chai Lee Goi. (2020). The River Water Quality Before and During the Movement Control Order (MCO) in Malaysia. Case Studies in Chemical and Environmental Engineering, Volume 2.

Chee Kong Yap (2019). Contamination in Pasir Gudang Area, Peninsular Malaysia: What can we learn from Kim Kim River chemical waste contamination? *Journal of Humanities and Education Development (JHED)* ISSN: 2581-8651

Department of Statistics, Malaysia (DOSM). 2021. *"Current population Estimates, Malaysia 2021".* Release Date: Thursday 15, July 2021.

Department of Statistics, Malaysia (DOSM). 2020. Compendium of Environment Statistics, Malaysia 2020

Economic Planning Unit – EPU. *“National Water Resources Study 2000 – 2050”.* Government of Malaysia, Department of Prime Minister’s Office 2000

Giri S, Oiu Z. (2016). Understanding The Relationship of Land Uses and Water Quality in Twenty First Century: A Review. *Jurnal Environment Management* 173:41-48

Mohamed Farid Noh. March 9, 2021. *“Sungai Kim Kim is Polluted Again”*.https://www.nst.com.my/news/nation/2021/03/672356/sungai-kim-kim-polluted-again. Retrieved on 27 July 2021.

Nazim Muradov, Mohamed Taha, Ana F Miranda, Krishna Kadali, Amit Gujar, Simone Rochfort, Trevor Stevenson, Andrew S Ball and Aidyn Mouradov (2014). Dual application of duckweed and azolla plants for wastewater treatment and renewable fuels and petrochemicals production. *Biotechnology for Biofuels 2014.7:30.*

Paul J. D. Janssen, Maya D. Lambreva, Nicolas Plumeré, Cecilia Bartolucci, Amina Antonacci, Katia Buonasera, Raoul N. Frese, Viviana Scognamigli and Giuseppina Rea (2014). Photosynthesis at the forefront of a sustainable life. *Frontier in Chemistry: Agricultural Biological Chemistry*. Volume 2, Article 36.

Yu, C., Sun, C., Yu, L. I., Zhu, M., Xu, H., Zhao, J., Zhou, G (2014). Comparative analysis of duckweed cultivation with sewage water and SH media for production of fuel ethanol. PLoS One, 9(12), e115023. Retrieved from https://doi.org/10.1371/journal.pone.0115023.

Yu Liu, Hua Xu, Changjiang Yu, Gongke Zhou, (2020). *Multifaceted roles of duckweed in aquatic phytoremediation and bioproducts synthesis*. GCB Bio Energy Bioproduct for a sustainable Bioeconomy.

Yuk Feng Huang. (2015). Quality of Water Resources in Malaysia”. DOI: 10.5772/58969. Retrieved from https://www.intechopen.com/chapters/47539

Mohd Naqib Azfar Mohd Roslan, Abentin Estim,Balu Alagar Venmathi Maran, Saleem Mustafa (2021). “*Effects of Aquatic Plants on Nutrient Concentration in Water and Growth Performance of Fantail Goldfish in an Aquaculture System”. Sustainability* 2021, *13*(20),11236; https://doi.org/10.3390/su132011236

Shahabaldin Rezania, Mohd Fadhil Md Din, Shazwin Mat Taib, Farrah Aini Dahalan, Ahmad Rahman Songip, Lakhweer Singh (2016). The Efficient Role of Aquatic Plant (Water Hyacinth) In Treating Domestic

Wastewater in Continuous System. *International Journal of Phytoremediation. Volume 18, 2016 – Issue-7. https://doi.org/10.1080/15226514.2015.1130018*

Alfarooq O. Basheer, Marlia M. Hanafiah, Mahmood Jamal Abdulhasan (2017). A Study On Water Quality from Langat River, Selangor. *Acta Scientifica Malaysia (ASM) 1(2)(20217) 01-04, Journal Homepage: http://www.razipublishing.com/journals/acta-scientificamalaysia-asm/archives.* ISSN: 2521-5051 (Print)

Nor Azura C.M (2021). River Water Quality Issues in Malaysia. *https://news.ump.edu.my/experts/river-water-quality-issues-malaysia*

DOSM, 2020. Compendium of Environment Statistics, Malaysia 2020