Algae as an Ecological Indicator in Creating a Sustainable and Ecological Environment

NURSYAFICA NADIA BINTI JOHARI
INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA
syaficanadia@gmail.com

RASHIDI OTHMAN
INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA
rashidi@iium.com.my

MUHAMMAD HANAFI ISMAIL
INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

WAN SYIBRAH HANISAH BINTI WAN SULAIMAN
INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

NURHANIE MOHD LATIF
INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

FARAH AYUNI MOHD HATTA
UNIVERSITI KEBANGSAAN MALAYSIA

RAZANAH RAMYA
UNIVERSITI KEBANGSAAN MALAYSIA

ABSTRACT

Environmental problems, including global warming and climate change widely acknowledged as one of the top global threats with far-reaching consequences. Despite the importance of decreasing CO_2 emissions or developing carbon-free energy sources, carbon sequestration should be a key issue since the amount of carbon dioxide that already exists in the atmosphere is great enough to cause global warming. Algae can fix carbon dioxide 10-50 times more than other terrestrial plants. It also has a rapid growth and multiplying rate much greater than higher plants. The study is aimed to explore algae characteristics and behaviour as potential ecological indicators and sequester agents for an unhealthy environment in an urban context. It was conducted by cultivating algae in controlled environments, which include different formulations, photoperiod and pH. Then, the selected species of algae will be evaluated and compared for their efficiency as potential carbon sequestration agents and lastly, to identify the colour changes of the algae that indicate the surrounding environment. These algae will be optimized and applied in landscape ecological design as phycoindicator and as a phycosequestration. Besides being a marker in creating a sustainable and ecological environment, it could help reduce the planet's natural impact by employing biological and sustainable initiatives that is aligned with the objectives of *maqasid shariah*. The principle of *Al Darra Yuzal* is very close to prevent all kind of harm in order to protect human live, wealth as well as future environment for next generation as what is being concluded in objectives of *shariah*.

Keywords: *Ecological Indicator, Environment, Maqasid shariah, Al Darra Yuzal, Carbon Sequestration*

INTRODUCTION

Climate change is widely acknowledged as one of the top global threats with far-reaching consequences. These include; rising sea levels, elevation in the concentration of atmospheric greenhouse gases, elongated heat waves with more frequency, loss of mass in Greenland and Antarctic ice sheets and biodiversity loss (Helen et al., 2021). In some cases, cultures have been affected, while some coastal cities have been flooded due to rising sea levels affecting more than 150 million people (Xu et al., 2019; Ekwebelem et al., 2020). Hence, a biological technique involving the application of microorganisms to capture and convert carbon dioxide to food, chemicals or fuel will be environmentally welcoming, greener, and cost-effective. Carbon Dioxide is captured using absorbent materials and released into the environment. Biological capture and sequestration of carbon using algae have been recognised as one of the world's most important and effective carbon sequestration methods (Moreira & Pires, 2016; Alami et al., 2021). Helen et al. (2021) also summarise that bio-capturing carbon using algae has been deemed environmentally friendly, economically feasible, and sustainable in the long run.

Algae can fix carbon dioxide 10-50 times more than other terrestrial plants. It also has a rapid growth and multiplying rate (a few hours), much greater than higher plants. Additionally, traditional manufacturing processes are unsustainable, utilising non-renewable feedstock and releasing large quantities of greenhouse gases, toxic side streams, and waste products into the environment (Arun et al., 2020). Implementing an algae-based biological as a carbon-capture approach facilitates carbon footprint mitigation and bioenergy production. (Choi et al., 2019). Therefore, all these are evidence that algae have strong environmental flexibility as they can tolerate and adapt to various extreme environmental conditions and enhance their applicability. Halal provides various guidelines which also include creating in halal environment.

LITERATURE REVIEW

Algae has been used for centuries in environmental assessments, especially in water bodies, as an indicator of a good ecosystem. Algae are also a major source of problems threatening many ecosystem goods and services. Besides capturing carbon dioxide through photosynthesis, they can respond to future challenges regarding its availability; algae can produce more oxygen than plants can produce. It is also directly responsible for almost 50% of the photosynthesis on earth (Cenci et al., 2017).

Architectural applications use algae to reduce the impact on the planet by employing biology to solve some of the world's biggest problems. The use of algae has many benefits over more expensive traditional treatment technologies. In comparison, traditional treatment requires enormous resources and discharges huge toxic byproducts, while algae are used to minimise environmental pollutants in an eco-friendly way (Priyadharshini et al., 2021). The efficiency of carbon captured by algae varies depending on their algal physiology, pond chemistry, and temperature. A study by Keffer and Kleinheinez (2002) revealed that carbon capture efficiencies are as high as 80% to 99% under normal conditions, with gas residence time obtained within two seconds. Algae efficiently utilize carbon dioxide, water and nutrients more than terrestrial plants because of their simple cellular structure (Pacheco et al., 2020). Hence, algae are considered to have high carbon mitigating and photosynthetic efficiencies, reducing atmospheric carbon emissions more rapidly than terrestrial.

Ecological civilization is a way of approaching social and ecological reform and represents a new standard of human existence that may be sustainable well into the future. Various landscape ecology measures have been used extensively throughout the landscape ecology community (Frohn, 2018). Algae is one the new measures that have the ability as a future landscape indicator due to many reasons proven by several studies, which are:

Table 1: Ability of algae as a future landscape indicator

Nos	Advantages	Author	Year
1.	Algae have the potential to address several issues concurrently, which is not feasible in traditional treatments in an environmentally sustainable way.	Daneshvar et al.	2019
2.	The ability of algae to sequester carbon is a promising alternative to the risk of global warming. The oxygen emitted will then be used to help purify the atmosphere.	Lutzu et al.	2021
3.	Remediation using algae is a cost-effective treatment that does not require large number of toxic substances or electricity to operate.	Sirakov et al.	2013

The table above demonstrates that algae can be used as future landscape indicators in creating more sustainable environments.

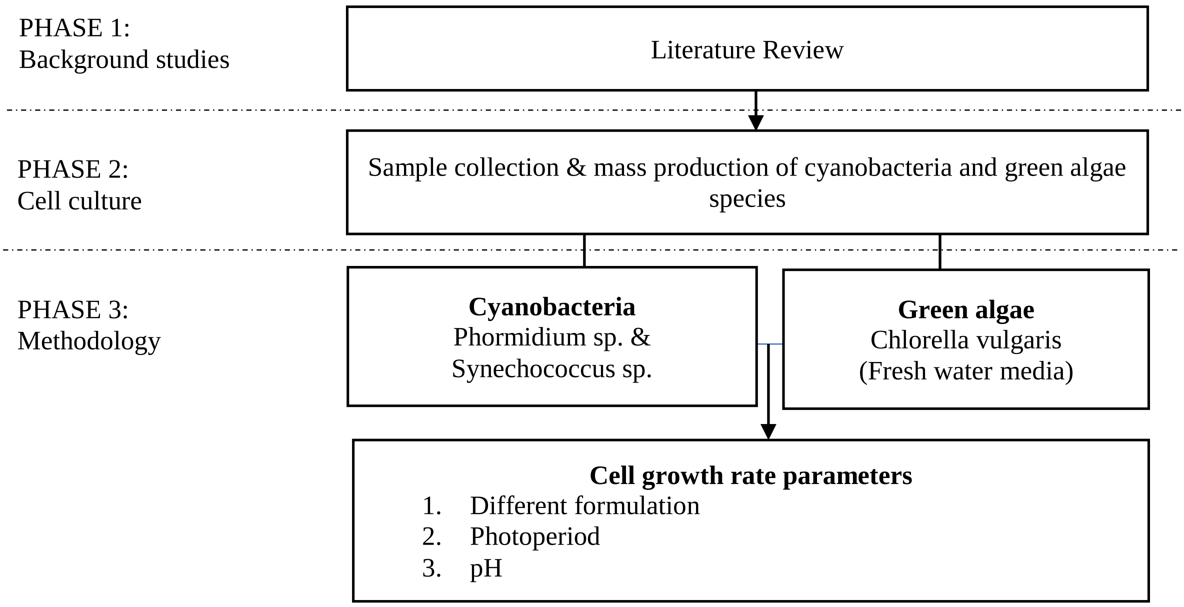
Algae are key primary producers in aquatic environments and represent several emerging genetic model systems (Hopes et al., 2016) Apart from playing an important role in human nutrition (FAO, 2014), photosynthesis of algal could provide about one-half of the oxygen (Price et al., 2012; Cenci et al.,2017). According to Mishra et al. (2022), Algae often occur in extreme environments, which reflects their ability to endure various natural and anthropogenic stresses. They need to survive with low concentrations of few essential nutrients in natural water and low availability of light and temperature. Apart from the limiting factors, they must survive and grow in adverse habitats enriched with salts, toxic metals and pesticides, elevated temperature, pH, UV-B radiation, and light intensity. Algae are the primary producers of water bodies (from rain ponds to oceans). Therefore, the tolerance range of algae to diverse stress factors has huge significance from an ecological standpoint. Also, the basic metabolic mechanism of algae is similar to higher plants.

The concept of Halal-Tayyiban (clean and pure) takes into account protection of health, food safety, animal rights, tincluding the environment, social justice and welfare in the food production, fair business practices, and ethics. It is seen as a more comprehensive system that aims to accomplish international standards compliance, making it universally acceptable. Tayyiban. There is also an environmentally friendly approach at the core of Halal Tayyiban that respects Mother Nature and also protects and cares for the environment. Rooted in the Islamic teaching, it is clearly noted that corruption of all kinds, including environmental corruption, which includes industrial pollution, environmental damage, and reckless exploitation and mismanagement of natural resources are disliked by Allah (SubhanahuWaTa'ala) (Idris, 2021).

To conclude, in this study, these algae will be optimized and applied in creating halal sustainable and ecological environment as phycoindicator (algae that indicate the health of the ecosystem), phytoremediation (algae is used to clean up contaminated environment), and as a phycosequestration (to sequester carbon involving algae).

METHODOLOGY

Table 2: Methodology



The culture was kept under Philips fluorescent light at 1800 lux of light intensity 25 µmol photons.$m^{-2}s^{-1}$ at intended photoperiod (light:dark) cycle, at 24:0, 12:12, 18:6, 6:8, and 0:24. The cultures were put under the temperature of 24 ± 1 °C for two weeks. Below is the list of all parameters conducted:

i. Algae strain: *Chlorella vulgaris* (Freshwater and marine), *Phormidium*, & *Synechococcus*
ii. Medium: Freshwater (BBM, Bristol, BG11, and Chu10)
iii. Photoperiod: All species in the different medium were put under five photoperiods (light: dark) cycle, at 24:0, 12:12,18:6, 6:8, and 0:24. The best photoperiod were chosen according to the fast growth and normal pigmentation of algae for next experiment of pH.
iv. pH: Different pH (3.0,5.0,7.0,9.0 & 11.0) was tested to determine the suitable pH for different species of algae.
v. Observed responses as in table 3

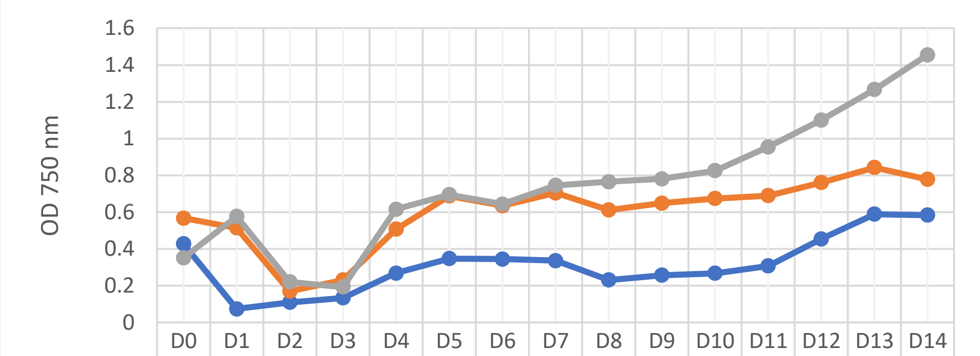
Table 3 Observed responses

Parameters	**Unit**
Cell growth rate per day	ABS
Density of cell	$\times10^4$ ML^{-1}
Cell chromaticity component:	CIELAB UNIT
Bluish green (-)/red purple (+)	A*
Yellow (+)/blue (-)	B*
Hue	H°
Biomass weight	%

EMPIRICAL RESULTS

Algae production grew more rapidly under the evaluated environment. This finding shows that they do not have to occupy arable land to grow, unlike terrestrial plants where they need large acres of land to plant and later, it takes years for them to grow. Figure 1 below shows the growth curves of the alga in a controlled environment. In 14 days, algae could have reached their stationary phase and later be used as a remediation agent in creating a sustainable environment.

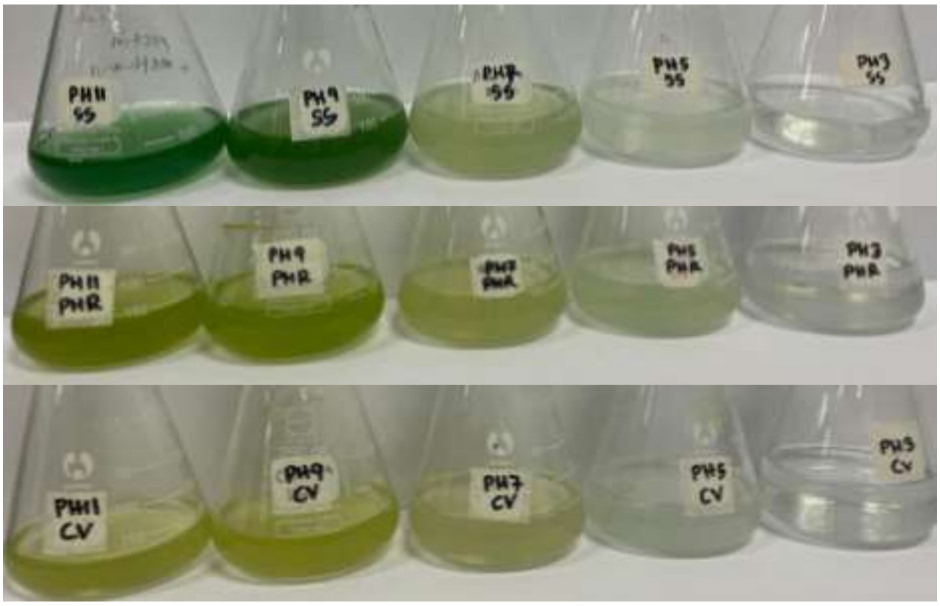
Figure 1: Growth curves of the microalgae species in 14 days



	D0	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14
SS	0.43	0.07	0.11	0.13	0.27	0.35	0.35	0.34	0.23	0.26	0.27	0.31	0.45	0.59	0.58
PHR	0.57	0.51	0.17	0.23	0.51	0.69	0.64	0.7	0.61	0.65	0.67	0.69	0.76	0.84	0.78
CV	0.35	0.57	0.22	0.19	0.62	0.7	0.64	0.75	0.77	0.78	0.83	0.96	1.1	1.27	1.45

Different pH range will significantly affect microalgae growth. The effect of pH on algal growth shows that the growth was influenced by pH at different ranges. Figure 2 below shows the intensity of the green color of microalgae (from the top: *Synchococcos, Phormidium and Chlorella Vulgaris).* The intensity become darker at pH 7 and above and decreased at pH5 and below.

Figure 2.: Growth observation of (from the top) *Synchococcos, Phormidium and Chlorella vulgaris*



At a higher pH (pH 7 and above), all species were observed with highest growth. They were grown at the lowest with pH 3. Figures 3 and 4 below display the different pigmentation of green depend on the culture growth. The highest growth is observed in pH 9 and pH 11. The pigmentation decreases accordingly as the pH level decreases. As the pH increases, the intensity of the algae is also influenced by the alkaline condition. It shows that algae can be a good indicator of the aquatic system's environmental conditions and bio-indicator pollution levels based on their changing color according to their pH.

Figure 3: Cell growth of (left) *Synchococcos* and (right) *Phormidium* from pH3 to pH 11 in BBM

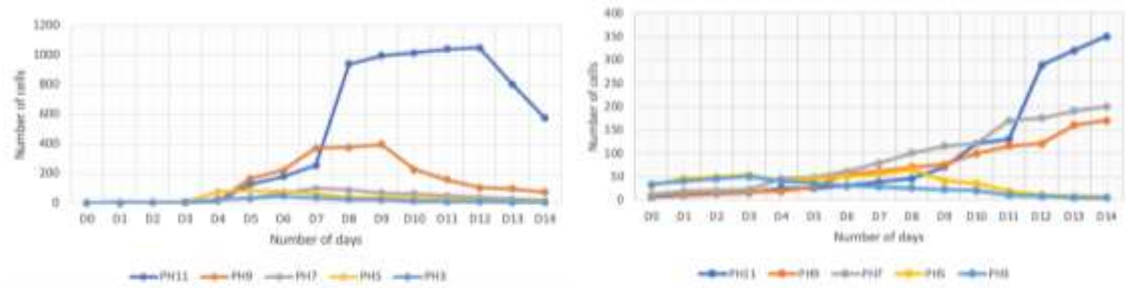
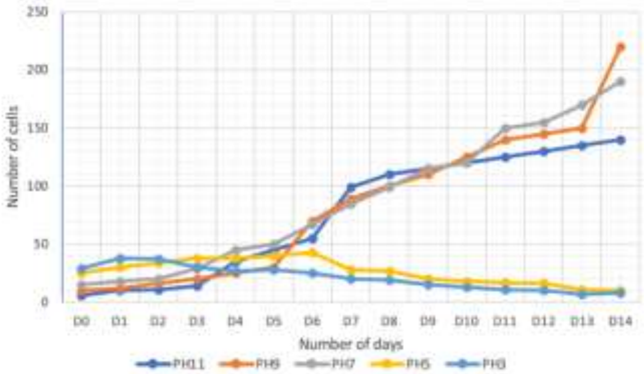


Figure 4: Cell growth of *Chlorella Vulgaris* from pH 3 to pH 11 in BBM



Some other key features of microalgae are the high photosynthetic efficiency. Microalgae have the ability to fix carbon dioxide 10-50 times more than other terrestrial plants (Moreira and Pires, 2016). Different environmental factors could influence their growth rates.

Next, Algae production was found to be significantly affected by medium formulation. The effect of time on cell growth is shown in Table below. Different media show a significant effect on algae growth. Table 4 and 5 illustrates the results of the effect of BBM on three different species: *Chlorella vulgaris*, *Phormidium*, and *Synechococcus* and it is evident that the time growth for each species is different even it is in the same medium formulation (BBM).

Table 4 Comparison between algae species in the same formulation (BBM) (D0-D7)

Species	D0	D1	D2	D3	D4	D5	D6	D7
SS	0.4281	0.1744	0.1097	0.1345	0.2688	0.3475	0.4455	0.5365
PHR	0.5672	0.5143	0.1705	0.231	0.5075	0.6879	0.6355	0.7045
CV	0.3515	0.5771	0.2214	0.1936	0.6164	0.6954	0.6441	0.7452

Table 5 Comparison between algae species in the same formulation (BBM) (D8-D14)

Species	D8	D9	D10	D11	D12	D13	D14
SS	0.5315	0.6578	0.7677	0.8079	1.0548	1.1896	1.2844
PHR	0.712	0.7492	0.8746	0.8904	1.0613	1.1242	1.2779
CV	0.7655	0.7809	0.8251	0.9553	1.1004	1.2669	**1.4548**

These three species started with low absorbent values and gradually increase until it reaches 1.0 starting on day 12 (indicated in red font). Therefore, it is concluded that *Chlorella vulgaris* shows the highest value, especially on day 14 (1.4548) compares to other species.
Next, table below shows the correlation between carbon weight and its chromaticity. Pollution can lead to changes in water color. Therefore, the pollution degree can be monitored by measuring the chromacity of water. In order to create halal sustainable environment, algae can be used as indicator to determine the environment conditions. Such as algae bloom which can become a serius public's health and environmental problem.

Table 6 correlation between carbon weight and chormacity for *Chlorella vulgaris* in BBM medium

	carbon weight		Chromacity (D14)		
CV (BBM)	**Weight**	**Cell Density**	**Δa***	**Δb***	**s**
ph 3	0.39	0.296	0.69	-1.4	0.2
ph5	1.53	0.556	1.45	-2.68	0.15
ph7	4.3	1.458	1.25	-2.71	0.16
ph9	4.63	1.466	1.6	-1.89	0.18
ph11	**8.43**	**1.468**	**0.41**	**-1.51**	**0.31**

* Positive a* indicates a hue of red purple and negative a*, of bluish green. Whereas positive b* indicates yellow and negative b* blue. The colour of achromatic or gray is when a* and b* = 0.

Table 6 data highlight the major effect the pH can have on the presence and accumulation of green pigment intensity and cell weight. There was positive relationship between pH conditions, saturation and green colour intensity of algae cell culture. **(masukkan data kat sini)**
In general, it can be concluded from the above results that environmental factors can exert some influences on the expression of green intensity pigments, cell density and total weight og algae cell.

Algae cultivation aims to create a halal sustainable environment. Since algae is a fast-growing species, the effort we would need to spend to cultivate them is very little. It is proved that the ability to grow fast is not a hassle since some algae reproduce quickly, and fast-growing algae is also a quality that can be used to absorb carbon dioxide on a large scale. Land-based plants contribute 52% of the total carbon-dioxide absorbed by the earth's biosphere. In comparison, ocean-based algae contributed 45% to 50% of that, which means that despite their small size, algae can absorb carbon-dioxide efficiently because of their comparatively short life cycles (Cai, 2018). Thus, algae can reduce the amount of carbon dioxide in the atmosphere if supported with an appropriate environment. The assessment of algae as indicators for aquatic environments are widely used but their potentials are not as yet fully recognized. Algae provide an integrated measure of water quality as experienced by the aquatic biota and have many biological attributes that make them ideal for biological monitoring (Barinove et al. 2010). They also respond quickly to the changes in water chemistry. For example, increases in water acidity due to acid-forming chemicals that influence lake pH levels and heavy metals discharged from industrial areas affect the color changes of the algae itself. Hence, this could impact drinking water supplies, aquatic life, and recreational water quality by supporting excessive algae growth. Nutrients reach waterbodies through agricultural and urban runoff, sewage discharges and detergents containing phosphorus.

CONCLUSION

Algae is outstanding among all the types of biological solutions to natural problems according to its ability, as mentioned before. Adopting it in landscape design could create a regenerative and restoration design. Besides being a marker in creating a sustainable and ecological environment, it could help reduce the planet's natural impact by employing biological and halal sustainable initiatives.

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