Physics and Chemistry of the Earth 129 (2023) 103356

Contents lists available at ScienceDirect

Physics and Chemistry of the Earth

journal homepage: www.elsevier.com/locate/pce

Leveraging microalgae utilization for anthropogenic CO2 emission abatement in Malaysian urban centre: Revisiting the sustainable development goal (SDG-13)

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ARTICLE INFO

Keywords:
Anthropogenic carbon dioxide
Environment
Greenhouse gases
Microalgae
Sustainable development goals (SDG-13)

ABSTRACT

Anthropogenic rise in atmospheric CO_2 level is a major contributor to global warming thus posing a threat to the rapidly increasing Malaysia's population. An in-depth investigation focusing on the use of microalgae for CO_2 abatement and pollution screening in Malaysia is thus necessary. The use of microorganisms like microalgae has been proposed as a means to mitigate the negative effect of anthropogenic CO_2. The advantages of using microalgae for pollution monitoring far exceed the drawbacks. Algal communities rely on CO_2 for photosynthesis because of their capacity to absorb and store more CO_2 for growth. This explains why algae are often used to clean the air in our communities. This is because they may be used on both a micro and a macro scale to assess the effects of environmental changes over time. Since the usage of specialized measuring devices may be expensive, replacing them with microalgae as a phytoremediation technology is a viable and cost-effective alternative. This can be utilized to quantitatively identify environmental changes, thus allowing stakeholders to make more well-informed decisions to ameliorate the long-term impacts. This is especially critical in industries like agriculture, where climate changes have a greater impact on agricultural yields. This review gives a brief description of how microalgae could be used for environmental assessment and CO_2 abatement relying on Malaysia as a case study.

1. Introduction

Climate change has been reported as the major driver of natural disasters which affected human lives and pose a serious risk to the continued existence of flora and fauna species. A consistent rise in carbon dioxide, water vapour, methane, nitrous oxide, and chlorofluorocarbons emissions has worsened climate change and its consequences on human health (Prasad et al., 2021). These are often identified as significant risk factors which predispose individuals to multiple health conditions such as respiratory infections, cardiovascular disease, and lung cancer (Choudhary, 2013). Symptoms and conditions such as eye irritation, skin disease, nausea and cardiovascular infection are identified as short-term effects of poor air quality (Paramesh, 2019; Sentian et al., 2019). Cardiopulmonary disease could occur as a result of constant binding of particulate matter with free radicals in the air (Choudhary, 2013). Individuals who are exposed to fine and coarse aerosol particles that reach the lung's alveoli are associated with high genotoxic potential. In large and medium-sized cities, there are higher prevalence of air pollution which is traceable to the increased waste gas emission from industry and road vehicles during traffic congestion. This declines the quality of air as well as increases the frequencies of fog and haze (Batterman et al., 2015). The release of toxic chemicals, particulate matter, and biological materials into the environment result in discomfort, damage or death to humans and other living organisms

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https://doi.org/10.1016/j.pce.2022.103356
Received 13 April 2022; Received in revised form 12 December 2022; Accepted 27 December 2022
Available online 10 January 2023

(Choudhary, 2013). It is broadly understood that air pollution within the atmosphere, exists either in solid, liquid or gaseous phase and it has destructive effects and alteration in the natural features of the atmosphere. It predisposes living things to health risks and is also responsible for the deterioration of the environment and the ecosystem (Choudhary, 2013; Dong et al., 2020; Kho et al., 2014; Sentian et al., 2019) Short- and long-term exposure to air pollutants poses different impacts on living things which could be categorized as health, environmental or economical-related (Sanidas and Papadopoulos, 2017).

According to the IPCC 2021 study, the global average temperatures between 2011 and 2020 have risen by 1.1 °C over the 1850 and 1900 average (Hitching-Hales and Lock, 2021). Malaysia is therefore on track to breach the 1.5 °C barrier by 2040, a temperature threshold stipulated in the Paris agreement on climate change and the one at which climate experts predict permanent changes to the overall climatic condition (Hitching-Hales and Lock, 2021). In recent years, the temperature rise is at the highest point and the lack of action is likely to further increase the average global surface temperatures throughout this decade and into the next century, with certain regions forecasted to warm significantly more (Fattah et al., 2021).

Alterations in urban land use are said to have a massive effect on climate changes in the surrounding area (Dey et al., 2021). The rise of human carbon emissions and decline of vegetation cover both causes the rise of land surface temperature (LST) (AlDousari et al., 2022). The combined effects of urbanization on ocean temperature, rainfall, evaporation, and hydrological space are negative (Wang et al., 2022). From roughly 280 parts per million in the eighteenth century to 414 parts per million in 2020, atmospheric CO_2 concentration has increased by more than 40 per cent from pre-industrial times. Emissions of CO_2 are expected to rise steadily from 2020 onwards, by an average of 0.7% each year, reaching 42.839 billion metric tons by 2050 (Fattah et al., 2021). Carbon dioxide in the atmosphere acts as a greenhouse gas by absorbing radiant energy from a larger spectrum of infrared wavelengths and blocking its escape back to space (Faisal et al., 2022). As a result, LST and urban heat island (UHI) impacts rise as human development expands and vegetation is lost (Al Kafy et al., 2021; Kafy et al., 2021a,b).

The expansion of cities is a relevant but less discussed concern with climate changes in Malaysia. Urbanization causes a phenomenon known as the UHI effect, which causes searing temperatures, especially in the city of Kuala Lumpur (AlDousari et al., 2022). Urbanization also contributes to poor air quality and the formation of haze and smog in cities. Malaysia also has a dismal ranking for possessing climate-resilient structures, as well as adequate alerting and emergency evacuation procedures to deal with extreme weather situations. According to the article, Malaysia was placed second to last in the Swiss Re Institute's April 2021 assessment (PreventionWeb, 2021). The impacts of vegetation cover reduction on air temperature, and pollutant emissions have been described by Rahaman et al. (2022). The carbon cycle and the stability of ecosystems in cities are both affected by rapid urbanization, human activities, and the variability of hydrological and land resources (Diep et al., 2022). The replacement of vegetative cover (VC) by expanding urban areas is a major contributor to the increase in LST, CO_2 emissions (CE) and greenhouse gases (Kafy et al., 2022a,b). Effective techniques were proposed to greatly enhance the carbon stock (CS) capacity and mitigate global warming and climate change effects in the fastest-growing cities. These included afforestation, reforestation, and urban greening initiatives via rooftop planting (Rahaman et al., 2022). Moreover, many studies reported the changes in meteorological factors as one of the reasons for elevated anthropogenic CO_2 concentration (Faisal et al., 2022). Previous studies have found conflicting results about the correlations between anthropogenic CO_2 emissions and meteorological conditions. Diverse regional and seasonal variables may account for the mixed results shown in the research on the effects of meteorological conditions on human activities. Despite the widespread recognition that climate has a role in air quality; this fact is often overlooked. Utilizing various regression models, Liu et al. (2013) analyzed the correlation between temperature changes and Taiwan's ozone levels. The effects of Beijing's weather on air pollution were studied by Dong et al. (2020), who also looked at other Chinese and Indian urban centres (Kanawade, 2016). Vietnamese researchers Trinh et al. (2019) explored how temperature inversion affected air pollution and environmental health in Vietnam.

As a result, reduction in the levels of global air pollution is one of the 17 Sustainable Development Goals (SDG) which was agreed by 193 world leaders to be the blueprint for development over the period 2015–2030. The 13th goal states: "… *By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management" (United Nations SDG).* (Assembly, 2015). An effort to combat climate change is the focus of Sustainable Development Goal 13, one of the 17 global goals set by the United Nations in 2015. To address this pressing issue, the Sustainable Development Goals provided a framework for people to engage collaboratively. Global warming and its effects are the explicit aims of this purpose, as stated in the strategic plan which outlines specific goals that must be met by the year 2030. The SGD-13 aims to improve developing nations' resilience and adaptation ability to climate-related risks and natural disasters. This was expected to incorporate climate change action, adjustment, impact reduction, and early detection indicators into government legislation, schemes, and planning through sensitization and individual and centralized administration on mitigating climate change, adjustment, impact reduction, and alert system. SDG-13 is planned to encourage systems for increasing capacity for effective conservation development and preparation in developing countries such as Malaysia. The mitigation actions to cope with extreme climatic changes involve cutting down the CO_2 emission and consequently their effects in Malaysia's urban centres.

Therefore, it is of the utmost importance right now to devise an effective plan to lower or stabilise atmospheric CO_2 levels in Malaysia's urban centre (Joint et al., 2011). Many studies have recommended several remote sensing-based approaches for monitoring environmental quality, but most of them only measure one aspect of the carbon footprint at a time (Kafy et al., 2021a,b; Cao et al., 2021). For example, they may only measure the urban heat island index, urban water usage, or urban green covering (Kafy et al., 2022a,b). Many researchers who studied the elements that affect environmental quality have concentrated on one explanatory variable, either studying environmental quality in and of itself or examining the effect of a single factor on air sustainability (Sun et al., 2020; Cao et al., 2021). Their investigations have also omitted an explanation of the importance and degree of the effects of each variable on air quality (Zhang et al., 2022). However, according to Shreyash et al. (2021), two main strategies exist for lowering emissions of carbon dioxide: cutting down on fossil fuels while simultaneously increasing the use of energy from renewable sources, and carbon dioxide capture and storage using a range of chemical, physical, and biological processes. Reducing carbon emissions by physical means has been widely studied. Even so, there are several technical and financial constraints on the current technology. As a result, it is essential to both advance current technology and provide

Table 1
Different microalgae species and anthropogenic CO_2 sources.

Microalgae Species	Anthropogenic CO_2 sources	References
Chlamydomonas algae culture	Tobacco smoke	Barati et al. (2022)
Scenedesmus obliquss	Flue gas from combustion chamber in a coke oven	Li et al. (2011)
Chlorella, Spirulina, Acutodesmus Obliquus and *Coelastrella* sp.	ydrothermal carbonization process	Durán et al. (2018)
Chlorella zofingiensis	Coal-fired boilers smoke	Aslam et al. (2018)
Chlorella sp.	Power plant flue gas	Kao et al. (2014)
Chlorella sorokiniana	Petroleum refinery flue gas	Kumar et al. (2014)
Chlorella vulgaris BEIJ 1890	Flue gas from cogeneration unit	Kaštánek et al. (2010)
Chlorella sp.	Combustion of coal	Taştan et al. (2016)
Chlorella sp. MTF-7	Flue gas from coke oven unit	Chiu et al. (2008)
Scenedesmus obliquus	Coke oven	Lin et al. (2018)
Nannochloropsis oculata	Flue gas from power plant	Cheng et al. (2019)
C. Vulgaris	Flue gas from cement factory	Rossi et al. (2018)
Chlorella sp.	Flue gas from power station	Yadav et al. (2015)
Chlorella	Flue gas from power station	Kim et al. (2018)
Chlorella Vulgaris	Flue gas from power plant	García-Cubero et al. (2018)

viable options. Biological carbon-dioxide fixation, along with many other considerations, appears to be a cost-effective and environmentally friendly alternative to physical and chemical processes. Carbon dioxide bio-fixation involves a specific usage of biological response for the quality assessment of inherent alteration in the environment (Sentian et al., 2019). The application of plant-based microorganisms for CO_2 bio-fixation is therefore an environmentally friendly, cost-effective, sensitive, feasible, predictive and easy technique when compared to other conventional methods (Parmar et al., 2016). It helps to determine the biological effects of pollutants on the immediate environment. This method, therefore, serves as a veritable technique in CO_2 abatement as compared to other sequestration methods (Parmar et al., 2016). The use of microalgae in CO_2 mitigation has been widely reported in urban habitats (Volterra et al., 2018; Moreira and Pires, 2020). Microalgae have earned a reputation as the most effective biological sequesters of CO_2. They have been used extensively to improve air quality by reducing CO_2 and enhancing oxygen (O_2) (Barati et al., 2022). There have been reports of microalgae being used to sequester carbon dioxide from the combustion gases of industrial facilities including power stations and

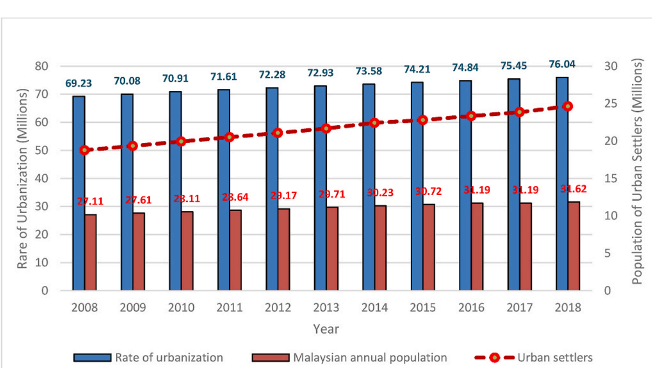

Fig. 1. Degree of urbanization in Malaysia (2008–2018). Adapted from the World Bank development indicators https://worldbank.org.
Sources: Adapted from World Bank (2019) report.

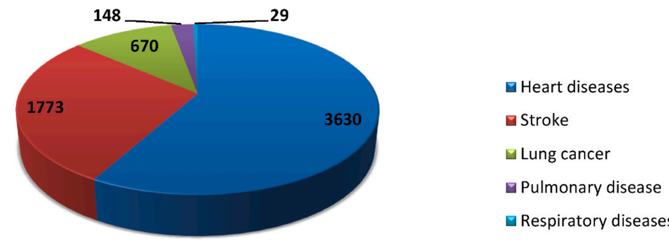

Fig. 2. Statistics of mortality from air pollution.

cement manufacturers (Zhao et al., 2021). Moreover, multiple patents have indeed been granted for the use of microalgae as indoor air filters. Table 1 shows the bio-fixation of anthropogenic CO_2 from different sources. Their bio-fixation capacity of microalgae is largely due to their high–CO_2–conversion capacity through the photosynthesis process. However, the specificity of certain algae for CO_2 absorption is dependent on their tolerance level. The introduction of microalgae as sequesters therefore has the potential of determining presence of contamination and adequately accessing the natural condition of the urban cities in Malaysia. The benefits accrued to the use of microalgae in CO_2 monitoring far outweigh their disadvantages. This is because of their usefulness in evaluating environmental changes at both the micro and macro levels (Parmar et al., 2016). The use of microalgae is highly promising and effective, which helps to differentiate between areas that are polluted and uncontaminated.

2. Anthropogenic CO_2 emission and phytoremediation

2.1. Overview of anthropogenic CO_2 emission

CO_2 is an essential component of photosynthetic activity in the algae community and this is partly due to its ability to absorb and subsequently capture extra CO_2 for its growth (Moreira and Pires, 2020; Packer, 2009). This explains the reason algae are usually utilized for the reduction of air pollutants in the environment. An elevation in the concentration of external CO_2 leads to an increase in the diffusion gradient for photosynthetic uptake and it also stimulates growth and development in hundreds of photosynthetic organisms (Wang et al., 2022). As a result of the bountifulness of CO_2 in the atmosphere, there is a corresponding elevation in the photosynthetic activity of algae due to a rise in CO_2 absorption (Yang et al., 2022). This indicates that the injection of CO_2 gas molecules increased the algae density. Therefore, the increase in the rate of absorbing CO_2 increases the rate of photosynthesis of the algae and as a result leads to an increase in their growth. The presence of anthropogenic CO_2 pollutants have been attributed as the major cause of global warming and climatic inconsistencies worldwide (Qi et al., 2019). CO_2 concentration has risen at an unprecedented rate due to industrialization and this is expected to double in years to come (Moreira and Pires, 2020). The increasing concentration of CO_2 in the atmosphere has resulted in a significant alteration of the lower plants in terms of species composition and density (De Lorenzo, 2022). A renewed approach for the assessment and reduction of elevated CO_2 has been put forward for consideration and this involves the use of microalgae as one of many possible solutions (Manisalidis et al., 2020).

Micro-organisms (such as plants, microbes, animals and plankton) have been utilized primarily as mitigation effects to safely reduce the effects of anthropogenic CO_2 in the environment (De Lorenzo, 2022). These plant-based bio-monitors are in some instances used to evaluate the environmental changes which can either be hazardous or beneficial. Microalgae are species that are utilized as a quantitative way of identifying environmental changes as a result of pollution scourge and also for controlling the exposure of biological systems to hazardous substances (Alwi et al., 2016). The merits of bio-indicators involve their inherent potential to identify the biological effects of pollution on the environment (Parmar et al., 2016). The effectiveness of epiphytic terrestrial algae in reducing anthropogenic CO_2 is partly a result of their short life cycle and non-complex nature. Therefore, there is a need for more studies to be carried out for long-term monitoring (Tang et al., 2020).

2.2. Phytoremediation potential of microalgae

Microalgae possess specialized structures for water and mineral absorption and conduction, without stems, leaves, or vascular systems such as the xylem and phloem (Alwi et al., 2016). These groups of microorganisms can grow in both aquatic and terrestrial habitats and this is largely due to their high tolerance level (Tang et al., 2020). As a result of the fact that terrestrial algae lack vascular systems (such as xylem and phloem), and some other adaptations required for them to live on land, they are usually found in moist and tropical regions than in dry ones. Common algae such as cyanobacteria and eukaryotic algae can be found essentially in all types of terrestrial environments (Brandenburg et al., 2019). Terrestrial algae are called this because they are independent of liquid water (Bižić et al., 2020). Researchers have shown that the environment had been adversely affected by the impact of changes in the climate as well as global warming which has further led to the alteration in the living microalgae's condition (Marchini et al., 2019).

The utilization of microorganisms such as microalgae has been suggested to alter the adverse impact of these changes on the environment. Microalgae usage has been proposed by various researchers like Moreira and Pires (2020) and Tang et al. (2020) to help in the reduction of CO_2 emission paths. Farrelly et al. (2013) reported in their study that algae have the potential of converting carbon (IV) oxides into harmless carbon biomass through photosynthesis. Different investigations have revealed the use of microalgae as bio-monitors in the screening and evaluation of environmental pollution. Zheng et al. (2013) reported that the extent of environmental pollution can be evaluated by exposing them to the algae population. Due to the high cost of establishing and maintaining a modern laboratory for microorganism culturing, the screening of urban areas largely requires several species of algae (Yamamoto, 2015). Take, for instance, the sudden rise in the CO_2 concentration in major cities in Malaysia has led to an unprecedented environmental change that alters the composition and diversity of the algae population (Yokoyama, 1994). However, despite the usage of microalgae in mitigating the effect of pollution, there is little information on their short- and long-term effects. The important characteristic of microalgae that qualifies them as bio-monitors for CO_2 pollution screening is their high tolerance level in any environment (De Mendonça et al., 2021).

Furthermore, CO_2 fixation using microalgae is a promising biological process for the conversion of anthropogenic CO_2 into harmless organic biomass. Klinthong et al. (2015) reported that the resultant organic biomass from the microalgae CO_2 fixation is generally made up of about 50% carbon (dry weight). One of the important pathways in the assimilation of CO_2 by terrestrial microalgae is known as oxygenated photosynthesis. This process involves the donation of electrons (from water) in the presence of light (photons). During the CO_2 fixation process, oxygen molecules are released (hydrolysis) as illustrated in the photosynthetic reaction equation below:

In the CO_2 fixation process, the photosynthetic reaction above is categorized into two pathways which include the light-dependent and dark-dependent pathways. Both pathways contribute largely to microalgae growth with the former involving the synthesis of two energy storage molecules (ATP and NADPH). The intermediate products are then converted into biomass during the fixation process (Klinthong et al., 2015).

3. Urbanization, CO_2 sources, and microalgae diversity in Malaysia

Malaysia is presently one of East Asia's most urbanized nations, and one of the world's rapidly urbanized areas (Shahbaz et al., 2016). In recent years, Malaysia's urban populace has experienced an 8% increment between 2004 and 2014 (Fielding, 2020). The development is due to the migration of rural dwellers to urban zones in the light of rapid economic and occupations. Over one decade, the number of Malaysian urban settlers has increased at an unprecedented rate from 18.77 million to 24.64 million which corresponds to around 23.8% increment (Bank, 2019). The rate of urbanization in Malaysia is one of the highest and most rapid in South East Asia with over 5% increment on an annual basis (The Star Online, 2019). This unprecedented urban population growth is forecasted to rise as many rural dwellers migrate daily to improve their standard of living for a better life. Fig. 1 shows the statistics of urbanization in Malaysia for a period of 10 years, between the years 2008–2018.

Consequently, air pollution in Malaysia has become prevalent in the last few decades with potential risk to the ever-increasing urban population (Sentian et al., 2019). Statistics have shown that about 6251 deaths were recorded in 2012 alone due to outdoor air pollution and this is largely responsible for up to 1 out of 10 mortality rates of every death in Malaysia (World Bank, 2019). The categorization of death resulting from air pollution-related cases in Malaysia is illustrated in Fig. 2.

The major sources of CO_2 emissions in Malaysia according to their percentage contribution include power plants (1.6%), motor vehicles (97.1%), industrial activity (1.1%) and other sources (0.2%) (MDOE, 2017). Among other factors, the vehicular activities contributed to about 1,410,134 metric tons of CO_2 in Malaysia as presented in Fig. 3.

A vivid example of the effects of anthropogenic CO_2 emission is the haze which is largely associated with forest fires from the neighbouring countries. For an instance, due to haze, thousands of schools were closed in September 2019. Also, because of the increasing health concern raised as a result of the toxic haze from the out-of-control blazes in Indonesia's Sumatra and Borneo islands, about 2500 schools were ordered to suspend classes in Malaysia - including nearly 300 in the smog-hit capital of Kuala Lumpur (Aljazeera, 2019); 298 schools in Sarawak, 138 schools in Selangor and 65 schools in Port Dickson and 25 schools in Putrajaya were ordered to close. To tackle the worsening haze, there was a regulation by Malaysia's Department of Environment (DOE) to ban open burning across the entire country except for purposes such as religious purposes, cremation, grilling/barbecue and flaring (Smith, 2019). Malaysia is ranked the third highest country for CO_2 emissions in Southeast Asia after Indonesia and Thailand (Kho et al., 2014; Sentian et al., 2019). Another factor responsible for the reoccurring CO_2 emissions in Malaysia is the rapid economic development which has resulted in an unprecedented level of anthropogenic CO_2 from motor vehicles and industries. The Geographic Association reported a high level of car acquisition in the Malaysian Peninsula which has triggered an

$$\underbrace{CO_2 + H_2O}_{\text{CO}_2\text{ fixation}} \quad \underbrace{\xrightarrow{\qquad\qquad\qquad}}_{\substack{\text{Free energy required for glucose} \\ \text{hydrolysis 2870 kJ/mol}}} \quad \underbrace{n\,[CH_2O] + O_2}_{\text{Assimilated biomass}}$$

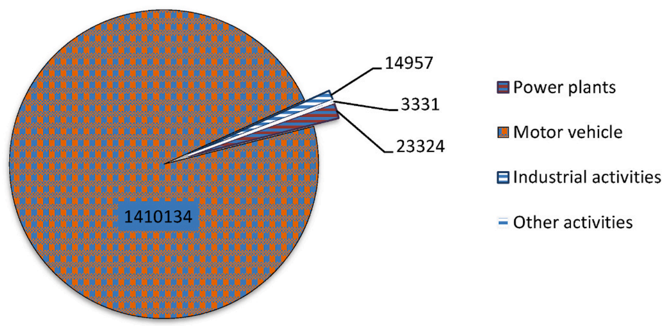

Fig. 3. CO_2 emission sources in Malaysia.

Table 2
Different species of microalgae and locations in Malaysia.

Available microalgae species	Location	References
Acanthophora spicifera, Gracilaria multifurcata	Pulau Gedung, Penang	(Terada et al., 2000; Zakaria et al., 2011)
Gracilaria changii	Pantai Morib, Selangor	(Sasidharan et al., 2011)
Kappaphycus alvarezii, Solieria anastomosa P. Gabrielson, *Gracilariopsis bailiniae,* Gracilaria firma	Semporna, Sabah	Thau et al. (2013)
Acanthophora spicifera, Amphiroa fragilissima, Gelidiella acerosa (Forsskal), *Gracilaria salicornia, Hydropuntia edulis, Laurencia papillosa, Laurencia* sp., *Ceramium* sp., *Pterocladia* sp., *Bostrychia* spp., *Caloglossa* spp., *Catenella* sp. Kappaphycus alvarezii	Kuala Similajau, Sarawak	(Kodikara and Pulukkuttige, 2012; Ong et al., 2010)
Gracilaria tenuistipitata	Kuah, Langkawi, Kedah	Terada et al. (2000)

astronomical increase in the air pollutants in a major urban area (Sentian et al., 2019). There are more than one thousand species of microalgae in the world with all the locations mentioned accounting for about 1.1% (i.e. 207,900 tons) of the cultivated microalgae globally. Due to the potential of microalgae bio-markers as CO_2 sequesters, it is then pertinent to study more on the species diversity in Malaysia. The microalgae population identified in some of the Malaysian states such as Penang, Sabah, Kedah, Sarawak and Selangor could be attributed to their ecological location (Table 2).

Many factors influence the growth of microalgae and these include light, temperature, salinity and water level. Alwi et al. (2016) in their study examined the possibility of an increase in the density of epiphytic terrestrial algae in Kuala Lumpur which was attributed to air pollution. The study was conducted to determine the number of *Coccomyxa confluens (*an epiphytic green alga) in the sites that are polluted and unpolluted. It was reported from the study that *Coccomyxa* is free-living in terrestrial biofilms, as soil algae, connected with mosses, planktonic in limbic ecosystems, in symbiotic associations with fungi and higher plants, and parasitic to marine mussels. It is usually used as a model organism, as its entire genome sequence has been published. Since *Coccomyxa* can serve as a frame of reference or for further experimentation, it allows it to be used for further research (Darienko et al., 2015).

C. confluens is particularly recognized as having the potential of tolerating pollutants effectively, especially carbon dioxide and nitrogen oxide (Ismail, 2013). In Malaysia, the distribution and diversity of microalgae over the years have yielded just 1.1% (207, 900 tons) of the cultivated amount when compared with other Asian countries such as China (58.4%), Indonesia (20.60%), the Republic of Korea (2.3%), Philippines (9.8%), and Japan (2.3%) (Rajkumar and Takriff, 2016). Zakaria et al. (2011) in their study identified a large distribution of red microalgae species such as *Acanthophora spicifera* and *Gracilaria multifurcata* in Pulau Gedung, Penang and their antibacterial potential and phytochemical constituents. Terada et al. (2000) identified and investigated six species of red algae which included a single species of *Halymeniaceae*, two species of *Solieriaceae*, and three species of *Gracilariaceae*. The *Gracilariaceae* family are mostly found in temperate states like Kedah, Sarawak, Selangor, and Penang which aligns with the report by Terada et al. (2000) which revealed that they are more adaptable to temperate regions.

4. Conclusion

As the urban Malaysian population continues to increase, the country's average temperature has risen and the humidity has decreased due to the increase in anthropogenic carbon dioxide. Power stations (1.6%), automobiles (97.1%), industrial activities (1.1%), and other activities (0.2%) make up most carbon dioxide emissions in Malaysia. Consequently, the use of motor vehicles is mostly responsible for the over 1,410,134 metric tonnes of CO_2 that have been released into the Malaysian atmosphere in recent years. This review, therefore, elucidated the potential of microalgae in cutting down the anthropogenic CO_2 in Malaysian urban areas. The use of microalgae for carbon dioxide fixation is an exciting prospect as a means of lowering CO_2 emissions. They have the capabilities to quantitatively detect changes in the environment and decrease anthropogenic CO_2, making them a promising option for improving air quality. This is of the utmost importance in fields such as agriculture, where climatic fluctuations have a bigger influence on crop production. The detrimental changes in climate patterns lead to a significant reduction in essential crop output, potentially leading to famine, as has occurred in most nations. This review provides a simplified discussion of the potential applications of microalgae in environmental assessment and CO_2 reduction by using urban centres in Malaysia as a given scenario. As a result, this offers information that stakeholders can use to make an educated choice about how best to lessen the impact of anthropogenic CO_2 on the environment over the long run.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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