Eco. Env. & Cons. 28 (4) : 2022; pp. (1682-1688)
Copyright@ EM International
ISSN 0971–765X

DOI No.: http://doi.org/10.53550/EEC.2022.v28i04.002

Periphytic Algal Succession with Temperature and Light Treatments

Aurel Satyaning Ati and Tri Dewi Kusumaningrum Pribadi

Department of Biology, Faculty of Mathematics and Natural Sciences, Padjadjaran University, Jl. Raya Bandung Sumedang Km. 21 Jatinangor, West Java, Indonesia, 45363

(Received 30 December, 2021; Accepted 7 February, 2022)

ABSTRACT

Periphytic algae are part of algal periphyton that are important in the microorganism community in the aquatic systems as they play an essential role as producers in the trophic and aquatic levels. The aim of this study serves to determine the structural differences of periphytic algae communities in both Cipeles River and Cisudajaya River, Sumedang, West Java. Accumulation of periphytic algae colonisation was performed with a number of temperature and light treatments using a square-shaped stone sized 2 cm x 2.5 cm x 1 cm for 28 days. Experiments were carried out with the temperatures set to 30°C and 33°C, as well as light intensities of 1000 lux and 2000 lux. Water as the medium is taken from the Cipeles River and Cisudajaya River. A number of different commercial hydroponic fertilisers as the growth nutrients for the periphytic algae were then added to the media. Once the experiments were fully performed, the results showed structural differences in the periphytic algae community from both Cipeles River and Cisudajaya River water media, where 25 types of periphytic algae from 10 classes were obtained from Cipeles River while the Cisudajaya River had 30 types of periphytic algae from 9 classes. In addition, an increase of colonisation was found in the periphytic algae samples taken from Cipeles River and Cisudajaya River, where they experienced biomass accumulation on Day 14 and Day 28. The optimal temperature for the periphytic algae colonisation in both samples is 30 °C, with the optimal light ranging betwen 1000 lux and 2000 lux.

Key words: *Temperature, Light, Succession, Periphytic algae, Algal Periphytic*

Introduction

Periphyton or Aufwuchs are organisms, including both heterotrophic and autotrophic, that grow heavily on submerged substrates (Wetzel, 2001). Periphytic algae are parts of periphyton that play an important role in the maintenance of their ecosystems by supporting food webs, removing nutrients from the water column, reducing flows, and also stabilising sediments (Stevenson, *et al*., 1996). The variability of the substrate in nature and the variety of suitable algae on each substrate cause different data to study periphyton quantitatively (Buczko and Acs, 1992), that subsequently leads us to think that habitat engineering is needed, including substrate and environmental factors in order to simplify the complexity of nature (Cattaneo and Amireault, 1992). The composition of periphytic algae community is affected by a number of factors including light, temperature, currents, substrate, scour by flooding, water chemistry, and grazing. Light and nutrients that interact with temperature can also affect biomass (Allan and Castillo, 2007). Light has the potential to contribute to many variations in physiology, population growth, and community structure of benthic algae (Hill, 1996). Light conditions directly affect the growth and photosynthesis of microalgae (duration and intensity). In addition, temperature is an important determinant of algal biomass and algal species composition in aquatic ecosystems (Rutherford, *et al*., 2000). An increase in temperature can also increase photosynthetic activity in algal communities (Pniewski and Sylwestrzak, 2018). It is suspected that exposure to temperature and light affects the periphyton succession process on artificial substrates. Light conditions directly affect the growth and photosynthesis of microalgae (duration and intensity). An increase in temperature can also increase photosynthetic activity in algal communities (Pniewski and Sylwestrzak, 2018).

This study was conducted not only to determine the structural differences in the periphytic algae community, but also to see the possible increase in the periphytic algae colonisation based on the exposure time during the temperature and light treatments on the periphytic algae samples from Cipeles River and Cisudajaya River water media. Both Cipeles River and Cisudajaya River are tributaries of the Cipeles sub-watershed, which flows to the Cimanuk watershed, the second longest river in the West Java Province. These two rivers have different regional hues as Cipeles River is situated near a settlement, while Cisudajaya River is located around rice fields. The absence of research on the succession of periphytic algae originating from the rivers in Sumedangarea makes it important to study the successional ability of periphytic algae as it highly provides us with basic information for the sustainability of the ecosystem.

Materials and Methods

Study Area

The succession experiments were performed at the Aquatic Ecology Laboratory of the Biology Study Programme, FMIPA - UNPAD between October and November 2020 for 28 days, while identification of the algal periphyton was carried out at the Water Quality Laboratory in the Center for Environment & Sustainability Science-CESS UNPAD. The coordinates of the sampling points are S06°53,197', E107°50,839' for the Cipeles River , and S06°50,816', E107°58,809' for Cisudajaya River.

Methods

Sample Preparation

Water samples for the succession experiment were taken from several sampling points in the water bodies of Cipeles River and Cisudajaya River, Sumedang. Periphyton sampling was carried out using the sweep method where substrate in the form of rocks and hydrophytes in the river was brushed using toothbrush and then rinsed with distilled water. The brushed part is the upper surface of the substrate that is exposed to sunlight and the roots of the hydrophytes. The results of the sweep were then put into a 100 ml Schott Duran glass vial and stored in a cool box without any light exposure prior to the experiment. Initial identification of population density of the periphytic algae was performed right before the experiment.

Experimental Set-Up

As nutrients, the water sample from Cipeles River and Cisudajaya River was given a 4 ml/l concentration of commercial fertiliser and poured into a 500 mL Erlenmeyer flask with 400 ml of water, where a square stone measuring 2 cm x 2.5 m x 1 cm was also put inside the flask as the attachment media for periphytic algae. In order to homogenise the temperature treatment, the Erlenmeyer flask was put into an aquarium measuring 120 cm x 50 cm x 60 cm containing tap water with a volume of 54 l, where a thermostat and a 16-watt LED lamp sized 40 cm were initially attached to adjust the lighting intensity to 1000 lux and 2000 lux, with additional dark-light ratio set to 12:12 using timer. Water temperature was maintained at 30 °C and 33 °C during the experiment. Additionally, a thermo-control was also placed on the inside of the aquarium to control the water temperature. *Resun Air-4000* aquarium air control with 6 liters/minute air flow was utilized to aerate each Erlenmeyer flask through an aerator hose, that is equipped with a 0.45 micron Sartorius filter. The aerator hose is connected to a straight glass pipe to circulate air into the Erlenmeyer flask, and L glass pipe is used to remove air from the same flask. A set of untreatedaquarium was used as control.

Sampling

Every 2 weeks for a period of 4 weeks, periphytic algae sediment samples were taken from the stone surface by sweeping, put into several 100-ml glass vials, and analysed using a microscope. In addition, the amount of the DO (dissolved oxygen) of the water in the flask was also measured using DO Meters every time a sample was taken. Sampling time was carried out from 09:00-12:00.

Data Analysis

The periphytic algae samples that have previously been put into 100 mL glass vials are taken using a pipette and dropped onto a Sedgwick Rafter until the volume reaches about 1 mL, where it is then put under microscope for identification using Freshwater Algae book *'Identification and Use as Bioindicators'* by Edward G. Bellinger and David C. Sigee. The data will then be analysed using the formulae for periphyton abundance, periphyton biomass, and ecological indices complying by Shannon-Wiener's Diversity Index (Odum, 1971), Evenness Index (Kreb, 1989), and Simpson Diversity Index (Berger and Parker, 1970).

Results and Discussion

Results

The highest level of total abundance of periphytic algae on Day 14 of the succession was found in the water media from Cisudajaya River with temperature and light treatment set to 33°C 1000 lux, whereas Day 28 showed the highest level of total abundance in the water media that was taken from Cipeles River with temperature and light treatment set to 33 °C 1000 lux (Table 1).

At the end of the experiment and based on the abundance obtained, the most optimal temperature for the periphytic algae growth is shown at 33 °C 1000 lux treatment for both Cipeles River and Cisudajaya River water media, namely 6835.8x104 ind/cm2 and 1125.6x104 ind/cm2 respectively.

Species richness in Cipeles River water media consists of 25 species derived from 10 classes (Table 2) while Cisudajaya River water media has 30 species that are derived from 9 classes (Table 3). The highest abundance of species comes from *Nitzschiaphilippinarum.*

The highest number of periphytic algae species in Cipeles River water media on Day 14 was found in the experiments with 30°C 2000 lux and 33°C 2000 lux treatments, with 14 species, whereas on Day 28, the composition of periphytic algae culture in Cipeles River water medium had its highest number at the 33°C 1000 lux treatment namely 15 species (Figure 1).

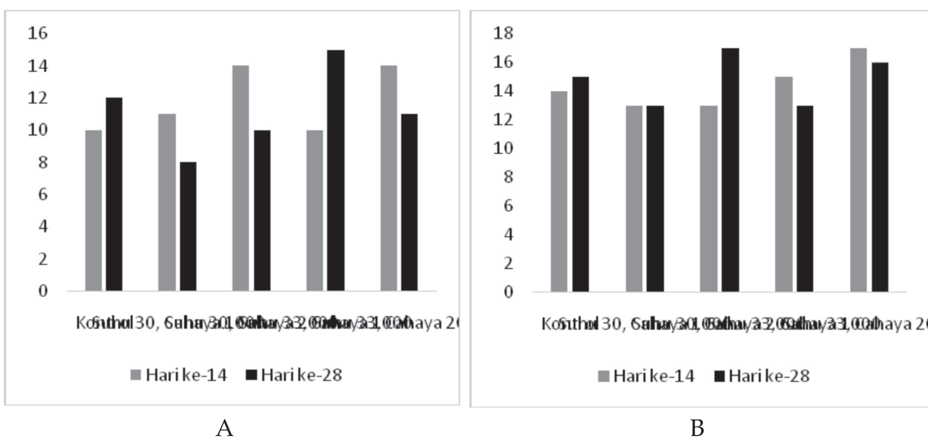

Fig. 1. The Total Number of Periphytic Algae Species: A. Cipeles River Water Media B. Cisudajaya River Water Media

Table 1. Total Abundance of Periphytic Algae

Day	Total Abundance ($x10^4$) Individual/cm^2									
	Control		30° 1000 lux		30° 2000 lux		33°C 1000 lux		33°C 2000 lux	
	A	B	A	B	A	B	A	B	A	B
Initial	2.2	6.5	2.2	6.5	2.2	6.5	2.2	6.5	2.2	6.5
14	8	13.4	26.2	290	33	103.8	26.2	1266.2	154.2	25.4
28	18	199.8	721.6	235.6	694.6	197.4	6835.8	1125.6	17.8	20.8

*Initial is the initial total abundance of the Cipeles River and Cisudajaya River water media as a whole in the entire Erlenmeyer flasks.
* A and B refers to name of the river, A: Cipeles River; B: Cisudajaya River.

The highest number of periphytic algae species in Cisudajaya River water media on Day 14 was found in the 33 °C 2000 lux treatment, namely 17 species, while Day 28 showed the highest composition of periphytic algae culture in Cipeles River water medium with 17 species during the 30 °C 2000 lux treatment (Fig. 1).

Discussion

The periphytic algae community obtained during the experiment had not yet reached the climax stage of periphytic algae succession. According to Szlauer-Lukaszewska (2007), succession of periphytic algae is divided into three stages: the initial stage: the first 2 weeks of periphytic algae development; the intermediate stage: weeks 3 to 11; and the adult stage: week 12. The time of succession in this study was carried out for 4 weeks, resulting that the periphytic algae community has not yet reached its stable stage.

The growth rate of microalgal cells is influenced by a combination of environmental parameters such as light intensity, photoperiod, and temperature in the culture system (Kitaya, *et al.*, 2008). Temperature is an important determinant of algal biomass and algal species composition in aquatic ecosystems (Rutherford, *et al.*, 2000). An increase in temperature has a direct positive impact on the rate of photosynthesis within a tolerable range. Specific response for a photosynthesis increases progressively as the temperature rises (Denicola, 1996). Accelerating rate of photosynthesis at high temperatures allows for a faster algae growth. DeNicola (1996) stated that the optimal temperature for most periphyton ranges from 10 °C to 30 °C.

Parmar, *et al.* (2011) stated that light intensity and light-dark photoperiod cycles are the main factors

Table 2. The Abundance of Periphytic Algae Species in the water media of Cipeles River

Name of Species	Species Abundance ($x10^4$) individual/cm^2										
	Initial	Control		30° 1000 lux		30° 2000 lux		33°C 1000 lux		33°C 2000 lux	
		14	28	14	28	14	28	14	28	14	28
Cyclotella sp.	0.02	0.2	0.8	17.6	2.2	12.8	2.6	6.4	1.6	2.2	1
Cymbellaaffinis	0.09					0.2			0.8		0.4
Fragilaria crotonensis	0.04			3.2		0.2				0.4	
Gomphoneis olivacea	0.19	2.2		0.2		0.4				0.2	
Gyrosigmascalproides	0.04	0.2					0.2				
Navicularadiosa	0.19		0.2	0.6		1	0.4	0.4	0.2	0.2	
Nitzschia philippinarum	0.06		8.6	0.8	710	5.2	446	6.8	6820	139.2	8.6
Pinnularia viridis	0.08	0.6	0.4	0.2	0.2	0.2	0.2		0.2		0.2
Surirella robusta	0.008		0.4			0.2			0.2		
Synedra acus	1.17	1.2	0.2	1.8	2.8	7	238	9.6	5.4	5	1.2
Pediastrum biredIatum	0.008							0.2		0.2	
Scenedesmus ovaliensis	0.07		0.6	0.6	5	1.4	1.6	1.4	2.2	3	2
Melosiragranulata	0.008	0.2		0.4				0.8	0.4	0.4	0.8
Merismopedia sp.				0.2	0.2						
Oscillatoria sp.									1		0.4
Phormidium lacuna	0.008		0.4			0.6	0.8	0.2	1		2.6
Stanieria sp.		0.4	2.6	0.6	1	0.2	1.6	0.2	0.4	0.2	0.4
Peranema sp.										0.2	
Phacuslongicauda			0.2								
Trachelomonas volvocina					0.2				0.2	0.4	
Cladophora sp.										2	
Lemaneafucina	0.02	0.4	0.8			2.8	3.2		1.8	0.6	0.2
Ulothrix zonata	0.008	0.2						0.2			
Tribonemaaequale		2.4	2.4			0.8					
Closterium parrectum	0.09								0.4		

*Note: the numbers 14 and 28 are sampling days where the sampling was carried out on Day 14 and Day 28.

that determine the growth rate in microalgal cultivation. According to Anderson (2005), the optimal light - dark regime was measured to vary between 12:12 and 16:8 for most cultures. Light above the absorption point causes light inhibition that may be offset by light entry of microalgae cells into very short light - dark cycle periods (Pulz, 2001). According to Pal, *et al*. (2013), in generally, microalgae culture requires light intensity (lux) ranging 1000-10,000 depending on the volume of the culture. Light intensity at higher depths with high cell concentrations needs to be increased in order to penetrate cultures, where 1000 lux is suitable for Erlenmeyer, while 5,000-10,000 lux is required for larger volumes (Coutteau, 1996). The temperatures and light intensities obtained during the experiments cannot be used as a benchmark to determine the stability of the periphytic algae community due to the fluctuating values of the data and insufficient amount of the climax succession.

All the periphytic algae obtained in all treatments were dominated by Bacillariophyceae class, and this dominance is presumably due to its high reproduction and adaptability. According to Odum (1998), the prevalent presence of Bacillariophyceae classes in the waters is caused by their ability to adapt to the environment, cosmopolitan, resistant to extreme conditions with high reproduction rate. The statement above is also supported by Praseno and Sugestiningsih (2000), where an increase in nutrient

Table 3. The Abundance of Periphytic Algae Species in Cisudajaya River Water Media

Name of Species	Species Abundance (x10^4) individual/cm^2										
	Initial	Control		30° 1000 lux		30° 2000 lux		33°C 1000 lux		33°C 2000 lux	
		14	28	14	28	14	28	14	28	14	28
Amphora persipulla	0.01	0.6	1.2	0.4		2.2	0.8	3.4	0.2	1.6	1.4
Cyclotella sp.	0.008		30	2.8	3.4	3.2	1.2	3	1	8.2	0.6
Cymbellaaffinis	0.24	0.8		0.2	0.2			0.2		0.2	
Fragilaria crotonensis	0.05	0.2	0.4		0.6		0.2				
Gomphoneis olivacea	0.04	0.2	0.2			0.2		0.2	0.2		
Gyrosigmascalproides	1.35	2.4	2	0.4	0.2			0.2		0.4	0.2
Navicularadiosa	2.14	1	1	2	0.2	2.2	1.4	2.6	5	1.8	1012
Nitzschia philippinarum	0.24	0.2	158	13.4	210	89.8	150	2.6	7.6	1242	89.6
Pinnularia viridis	0.008						0.2				0.4
Stenopterobia sigmatella			0.4			0.4	0.2	0.8		0.2	
Surirellarobusta		0.6			0.2			0.2			
Synedra acus	2.25	2.4	3.6	2.8	10.8	1	2	8.6	2.2	1	2.4
Monoraphidium sp.							0.2			0.2	0.6
Pediastrum biredialum	0.01	0.2		0.2				0.2			
Scenedesmus ovaliensis	0.03		0.4	0.4	0.2	0.2	34	0.2	1	0.2	5
Melosiragranulata		0.4	0.2						0.4		0.2
Merismopedia sp.											0.2
Nostoc sp.							0.6		0.2		
Oscillatoria sp.					1.4	1.2	0.4	2.6		2	
Phormidiumlacuna	0.008		0.2			1.6	0.8	0.4	1	5.2	11.6
Spirulina sp.					3.6	0.2	4.8		1	0.2	0.2
Stanieria sp.		1.2	0.8	1.4	0.2	1.4	0.4		0.4	0.6	0.2
Trachelomonas volvocina				0.2				0.2			
Cladophora sp.										1	
Lemaneafucina				4.6							
Terpsinoemusica		0.2									
Ulothrix zonata			0.2	0.2	4.6		0.2		0.8		0.8
Tribonemaaequale		3	1.2			0.2	0.6			1	
Closterium parrectum	0.008										
Cosmarium punctuatum	0.01									0.4	0.2

* Note: the numbers 14 and 28 are sampling days where the sampling was carried out on Day 14 and Day 28.

concentration will enable the, diatoms to reproduce three times within 24 hours alone. Bacillariophyceae also possestools in the form of long and short gelatinous stalks with gelatinous cushions that are semispherical in shape and two additional layers of cell walls stacking on top of one another to strongly attach to substrates, and also mucus on the lid that makes it easier to move around. The ability to adhere to the substrate surface better than other types of periphyton causes the presence of Bacillariophyceae to dominate in an ecosystem (Suwartimah *et al.*, 2011).

Based on the observation time, Bacillariophyceae class appears to be the largest class that composes the periphyton community in each observation, and subsequently reflects the competitive advantage of Bacillariophyceae that is associated with higher growth rates at high temperatures. According to Biggs (1988), diatom taxa are capable of rapid colonisation. The ability to rapidly colonise is causing the diatoms to also create its initial peak biomass. The species with the most occuring prevalence during the experiment in all treatments was *Nitzschia philippinarum*, while *Nitzschia* sp. is an adaptive species (Shen *et al*., 2018) and *Nitzschia* sp. happens to be microalgae that are found abundantly in waters due to its ability to survive in extreme conditions (Ilhami, 2015).

In conclusion, the periphytic algae community that was obtained during the experiments with a number of temperature and light treatments has not yet reached the climax state of the periphytic algae succession. The growth rate of the microalgal cells is influenced by a combination of environmental parameters such as light intensity, photoperiod, and temperature. The periphytic algae obtained in all treatments were dominated by *Nitzschia philippinarum* from the Bacillariophyceae class.

Acknowledgements

This study was supported by the research from RISTEKDIKTI for the scheme of Fundamental Research 2020 with contract number 1827/UN6.3.1/LT/2020. The authors cordially thank Aep Saeppudin from Aquatic Laboratory of Centre for Environment and Sustainability Science Universitas Padjadjaran for the plankton identification.

References

Allan, D. J. and Castillo, M. M. 2007. *Stream Ecology Structure and Function of Running Waters. Second Edition.* Springer, Dordrecht.

Anderson, R. A. 2005. *Algal culturing techniques*. Academic Press Publication, West Boothbay Harbor.

Biggs, B. J. 1988. Artificial substrate exposure times for periphyton biomass estimates in rivers. *New Zealand Journal of Marine and Freshwater Research.* 22(4): 507-515.

Buczko, K. and Acs, E. 1992. Preliminary studies on the periphytic algae in the branch-system of the Danube at Cikolasziget (Hungary). *Studia Botanica Hungaria*. 23: 49-62.

Cattaneo, A. and Amireault, M. C. 1992. How artificial are artificial substrata for periphyton?.*Journal of North American Benthological Society.* 11: 244-256.

Chindah, A. C., Braide, S. A., Amakiri, J. and Ajibulu, O. O. 2009. Periphyton succession in a waste water treatment pond. *Revista UDO Agricola*. 9(3): 681-699.

Coutteau, P. 1996. *Manual on the production and use of live food for aquaculture.* FAO Fisheries Technical.

Denicola, D. M. 1996. Periphyton responses to temperature at different ecological levels.In: R. J. Stevenson, M. L. Bothwell and R. L. Lowe (ed.). *Algal Ecology: Freshwater Benthic Ecosystems.* Academic Press, San Diego.

Hill, W. 1996. Effects of light. In: R.J Stevenson, M.L. Bothwell & R.L. Lowe (ed.) *Algal Ecology*. Academic Press, California.

Ilhami, B. T. K., Japa, L., Astuti, S. P. and Kurnianingsih, R. 2015. Pengaruh perbedaan umur panen terhadap kandungan lemak *Nitzschia* sp. *Jurnal Biologi Tropis*. 15(2): 145-155.

Kitaya, Y. L. 2008. Effects of temperature, photosynthetic photon flux density, photoperiod and O_2 and CO_2 concentrations on growth rates of the symbiotic dinoflagellate, *Amphinidium* sp. *J. Appl. Phycol*. 20: 737-742.

Krebs, 1989. Ecology: T*he Experimental Analysis of Distribution and Abundance. Third Edition*. Harper and Row Publishers, New York.

Lamberti, G. A. and Resh, V. H. 1985. Comparability of introduced tiles and natural substrates for sampling lotic bacteria, algae and macroinvertebrates. *Freshwater Biology*. 15 : 21-30.

Maggs, A. C. and Callow, M. E. 2002. *Algal Spores.* Macmillan Publishers, Ltd, London.

Murdock, J. N. and Dodds, W.K. 2007. Linking benthic algal biomass to stream substratum topography. *Journal of Phycology.* 43 : 449-460.

Odum, E. P. 1998. *Dasar-dasar Ekologi (Fundamentals of Ecology)*. Diterjemahkan oleh Yj. Samingan. Gajah Mada University Press, Yogyakarta.

Pal, S. W. 2013. Evaluation of relationship between light intensity (lux) and growth of *Chaetoceros muelleri*. *Journal of Oceanography and Marine Research*. 1(3): 1-4.

Parmar, A., Singh, N. K., Pandey, A., Gnansounou, E. and Madamwar, D. 2011. Cyanobacteria and microalgae: a positive prospect for biofules. *Bioresour. Technol*. 102: 10163-10172.

Pniewski, F. and Sylwestrzak, Z. 2018. Influence of short periods of increased water temperature on species composition and photosynthetic activity in the Baltic periphyton communities. *Biologia*. 73: 1067-1072.

Praseno, D. P. and Sugestiningsih, 2000. *Retaid di Perairan Indonesia*. P30-LIPI, Jakarta.

Pulz, O. 2001. Photobioreactors: production systems for phototrophic microorganisms. *Appl. Microbiol. Biotechnol.* 57: 287-293.

Reynolds, C. S., Padisak, J. and Sommer, U. 1993. Intermediate disturbance in the ecology of phytoplankton and the maintenance of species diversity: a synthesis. *Hydrobiologia*. 249: 183-188.

Rutherford, J. C., Scarsbrook, M. R. and Broekhuizen, N. 2000. Grazer control of stream algae: modeling temperature and flood effects. *Journal of Environmental Engineering*. 126: 331-339.

Shen, R., Ren, H., Yu, P., You, Q., Pang, W. and Wang, Q. 2018. Benthic Diatoms of the Ying River (Huaihe River Basin, China) and Their Application in Water Trophic Status Assessment. *Water*. 10(1013): 1-16.

Stevenson, R. J., Bothwell, M. L. and Lowe, R. L. 1996. *Algal Ecology: Freshwater Benthic Ecosystems*. Academic Press, USA.

Suwartimah, K., Hartati and Wulandari, 2011. Komposisi Jenis dan Kelimpahan Diatom Bentik di Muara Sungai Comal Baru Pemalang. *Ilmu Kelautan*. 16(1): 16-23.

Szlauer-Lukaszewska, A. 2007. Succesion of periphyton developing on artificial substrate immersed in polysaprobic wastewater reservoir. *Polish J. of Environ. Stud.* 16(5): 753-762.

Taraldsvik, M. and Myklestad, S. 2010. The Effect of pH on Growth Rate, Biochemical Composition and Extracellular Carbohydrate Production of The Marine Diatom *Skeletonema costatum*. *European Journal of Phycology*. 35(2): 189-194.

Wetzel, R. G. 2001. *Limnology. Lake and River Ecosystems, 3rd Edition.* Academic Press, San Diego.