# Diurnal Variations in the Physico-Chemical Characteristics at Como Region in a Man-Made Reservoir, Kenyir Lake, Malaysia

*CHATERJI, A., MITHUN, S., MUHD HANIFF, M.Y., PRADEEP, P.J., SRIJAYA, T.C., BRYAN, R.N., ALI, M.M., ANUAR, H. and SHAHAROM, F.

*Institute of Tropical Aquaculture, Universiti Malaysia Terengganu, 21030 Kuala Terengganu, Malaysia*

**Corresponding author: anilch_18@yahoo.co.in*

*Abstract:* Physico-chemical parameters of Kenyir Lake at Como region were measured to assess the health of the ecosystem. Although the difference in air temperature was 27%, the surface water showed 2.5% variation within 24 hours. The fluctuations of water temperature (30.4-31.7°C) at depths of 3 and 6 m were 3.5 and 2.2% respectively within 48 hours. The pH values until 6 m depth ranged from 6.7-7.2. In a similar manner, the dissolved oxygen (DO) at the surface and 3 and 6 m depths were within the range of 8.5-10.3 mg/l during 48 hours. Fluctuations of total dissolved solids were only 4 to 5.5% whereas chlorophyll a was 0.0075 µg/l (2400 hrs) and 0.1038 µg/l (1800 hrs) with 93.7% fluctuation. The hydrogen sulphide ($H_2S$), nitrate ($NO_3$) and phosphate ($PO_4$) contents were always below the detectable range in the surface water whereas at 3 m, these values were; 1.0-1.6 µg/l ($H_2S$), 0.26-0.50 µg/l ($NO_3$) and 0.01-0.09 µg/l ($PO_4$) and at 6 m the values were 1.0-3.6 µg/l ($H_2S$), 0.20-0.40 µg/l ($NO_3$) and 0.02-2.30 µg/l ($PO_4$). Considering the optimal values of DO, pH and other chemical parameters in Kenyir Lake, it has been presumed that the reason for mass mortality and slow growth of the fish cultured in cages could be related to high temperature regime (>30°C).

**Keywords:** Kenyir Lake, diurnal variation, environmental parameters

*Abstrak:* Parameter fiziko-kimia di kawasan Como di Tasik Kenyir telah diukur bagi menilai kesihatan ekosistemnya. Walaupun perbezaan suhu udara adalah 27%, permukaan air menunjukkan variasi 2.5% dalam masa 24 jam. Perbezaan suhu air (30.4-31.7°C) di kedalaman 3 dan 6 meter adalah masing-masing 3.5 dan 2.2% dalam masa 48 jam. Nilai pH di kedalaman 6 m adalah di antara 6.7-7.2. Pada masa yang sama, oksigen terlarut (DO) permukaan dan di kedalaman 3 m dan 6 m adalah di antara 8.5 hingga 10.3 mg/l dalam masa 48 jam. Perubahan jumlah pepejal terlarut adalah hanya 4 hingga 5.5% di mana klorofil a adalah 0.0075 µg/l (jam 2400) dan 0.1038 µg/l (jam 1800) dengan kadar perubahannya sebanyak 93.7%. Kandungan hidrogen sulfida ($H_2S$), nitrat ($NO_3$) dan fosfat ($PO_4$) di permukaan adalah sentiasa di bawah tahap yang boleh dikesan manakala di kedalaman 3 m, nilainya adalah 1.0-1.6 µg/l ($H_2S$), 0.26-0.50 µg/l ($NO_3$) dan 0.01-0.09 µg/l ($PO_4$) dan pada 6 m nilainya adalah 1.0-3.6 µg/l ($H_2S$), 0.20-0.40 µg/l ($NO_3$) dan 0.02-2,30 µg/l ($PO_4$). Dengan mengambil kira nilai optimum DO, pH dan parameter kimia lain di Tasik Kenyir, penyebab kematian dan pertumbuhan perlahan ikan dalam sangkar adalah mungkin disebabkan oleh suhu yang tinggi (>30°C).

## Introduction

Diurnal variations in physico-chemical characteristics have been the subject of considerable interest in the aquatic ecology since 1930 (Wiebe, 1929; Marshall, 1997; Jones *et al.*, 2003; Nimick *et al.*, 2005; Talling and Lemoalle, 2006). In many of the earlier studies attention was mostly drawn to know the diurnal variations in various environmental parameters of ponds and rivers but afterward interest started generating to expand the scope of studies towards swamps, ditches and streams. Diurnal cycles are known to be important in studying the oxygen and carbon dioxide dynamics however such types of studies are meager in man-made tropical lakes like Kenyir Lake. Diurnal variations in nutrients and physico-chemical variables have been observed to fluctuate significantly on a daily cycle but the extent of this phenomenon occurring in Kenyir Lake of Malaysia has not thoroughly been investigated so far.

Kenyir Lake is the largest man-made lake in South East Asia which is located in the district of Hulu Terengganu (Latitude 4° 47' and 5° 15' N; Longitude 102° 32' and 102° 55' E). The lake originated primarily from Terengganu and Terenggan rivers which covers a vast area of 260 square kilometres with 340 small islands surrounded by one of the oldest tropical rainforest in the world (Furtado *et al.*, 1977). The maximum depth of the lake is ~145 m with a mean depth of 37 m covering an area of 38,000 hectares

(Yusoff, 1996; Yusoff *et al.*, 2002; Yusoff, 2007; Rouf *et al.*, 2010). The lake experiences two monsoon seasons, i.e. the north-east (November-January) and south-west (May-October). Average surface temperatures during 1968-1991 were between 24.2 and 32.0°C (Yusoff and Lock, 1994) and 24.7 and 31.1°C during 2007 and 2008 (Amal *et al.*, 2010).

In Kenyir Lake a dam is constructed to generate electricity for Malaysian consumption. The reservoir provides considerable economic returns to the majority of population especially farmers living in the vicinity. A number of projects have been launched by the Government of Malaysia for improving the economy of the poor people and making maximum use of this water body for the benefit of the society. A cage culture project for growing economically important freshwater fishes has also been launched by the Department of Fisheries at Como region, Kuala Barang. These cages have been given to private entrepreneurs for culturing commercially important species of fishes. However, heavy mortality and slow growth of caged grown fishes have been a disappointing factor for the fishermen for the past few years. This has prompted us to study the behavior of the lake in terms of analyzing various physico-chemical parameters with a hope that diurnal changes in these parameters will provide an insight and appropriate measures which could be adopted in predicting the sensitivity and conduciveness of the lake.

## Materials and Methods

A study on the diurnal variations in the physico-chemical parameters of Como region located at the Kenyir Lake was carried out and for that one sampling station was selected near to the floating cage (Plate 1). As the depth of cage was ~3 m, water samples for diurnal studies were collected from the surface, 3 and 6 m depths (photic zone) at this station. The samples were collected at an interval of 6 hours i.e. morning, noon, evening and night during 48 hours. Parameters like air temperature, temperatures at the surface and different water columns ranging from 3-6 m depths, water pH, dissolved oxygen (DO) and total dissolved solids (TDS) were measured by a YSI meter (YSI Hand Operated Oxygen: Temperature Meter Model 550 A) whereas hydrogen sulphide ($H_2S$), nitrate ($NO_3$) and phosphate ($PO_4$) concentrations were analyzed by Hatch kit (Model Hatch DR/2400) using methylene blue, cadmium reduction and ascorbic acid methods, respectively. The chlorophyll *a* was also measured following the protocol given by Parsons *et al.* (1984). Water samples at different depths were collected by a Niskin water sampler (Model 1010X).

All data were analyzed using 2-way ANOVA with significance levels between all physic-chemical parameters and for interacting effects Tukey analysis was used.

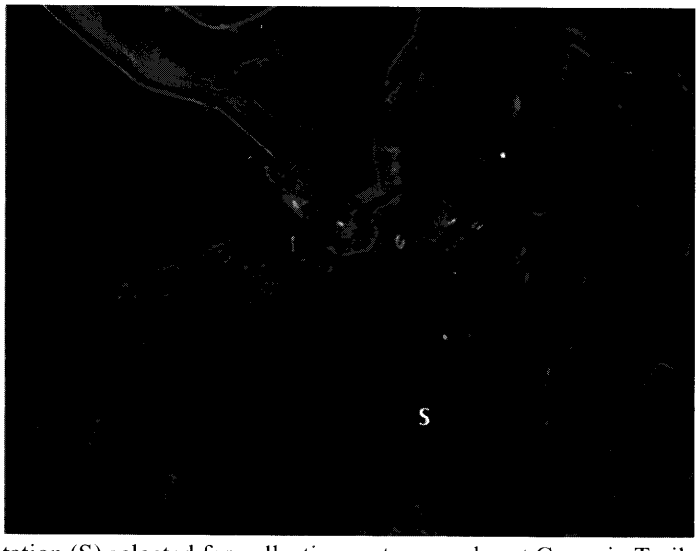


**Plate 1:** Station (S) selected for collecting water samples at Como in Tasik Kenyir

## Results

Data collected for air and water temperatures at an interval of 6 hours till 48 hours are presented in Fig. 1. The air temperature was the lowest at 0600 hrs (30.5°C) whereas it was the maximum (33°C) at 1200 hrs with 27% fluctuation between the lowest and highest temperatures (Fig. 1). The surface temperatures of the water were between 30.9 and 31.7°C with only 2.5% fluctuation during 48 hours of observation. At the depth of 3 m, the range of temperature was between 30.3 and 31.4°C with only 3.5% fluctuation whereas at 6 m it was between 30.2 and 30.9°C with only 2.2% difference during 48 hours (Fig. 1). It was quite evident that the temperature variation between depths 3 and 6 m was only 3.6% during 48 hours irrespective of fluctuation of air temperature by 27% ($P<0.05$) (Fig.1). The pH of surface water ranged between 6.7 and 7.3 (Fig. 2). Similarly at the depths 3 and 6 meters, the pH values were between 6.7 and 6.9 m and 6.7 and 7.2 respectively (Fig. 2). Similarly, the dissolved oxygen was the maximum in surface water (10.1 mg/l) at 1200 hrs whereas at 3 and 6 m depths, the values did not show much deviation from 6-9 mg/l (Fig. 3). The minimum DO values were at the surface during early hours (~7 mg/l), however, during night hours, dissolved oxygen concentrations were between 8.5 and 9.7 mg/l at 3 and 6 m depths respectively (Fig. 3). The variation in TDS values in surface waters were not much during 48 hours where only 5.5% fluctuation was recorded (Fig. 4). Values of TDS were between 0.017 and 0.031 g/l at surface (Fig. 4). The fluctuation of TDS at 3 and 6 m depths was only 4.6% during 48 hours of the observation.

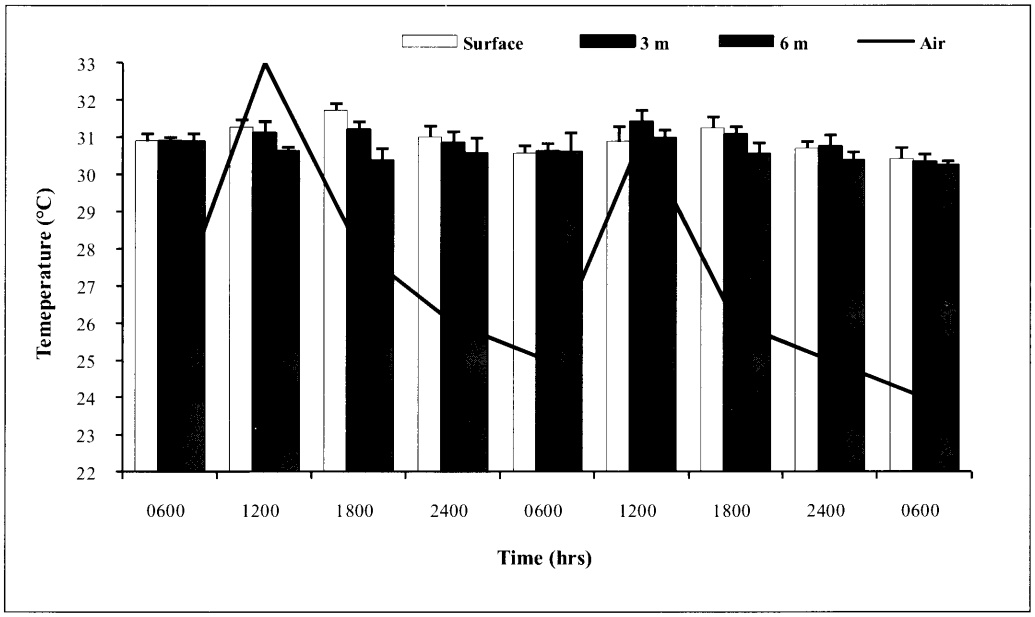


**Figure 1:** Variation in temperature at surface, 3 and 6 m depths of Kenyir Kaje during 48 hours of observation

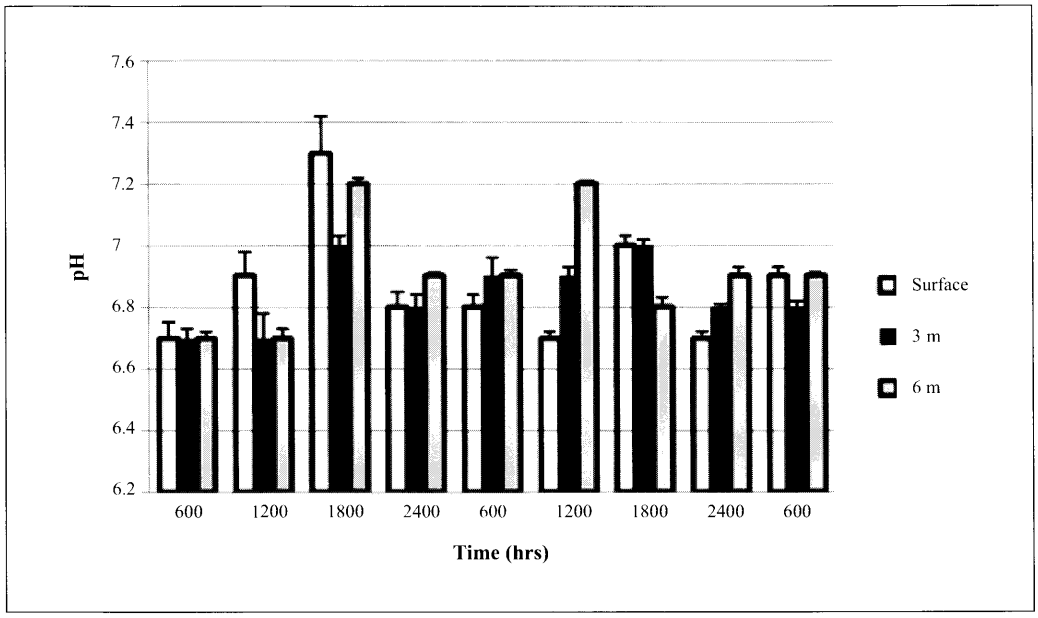


**Figure 2**: Variations in pH at surface, 3 and 6 m depths of Kenyir Lake during 48 hours of observation

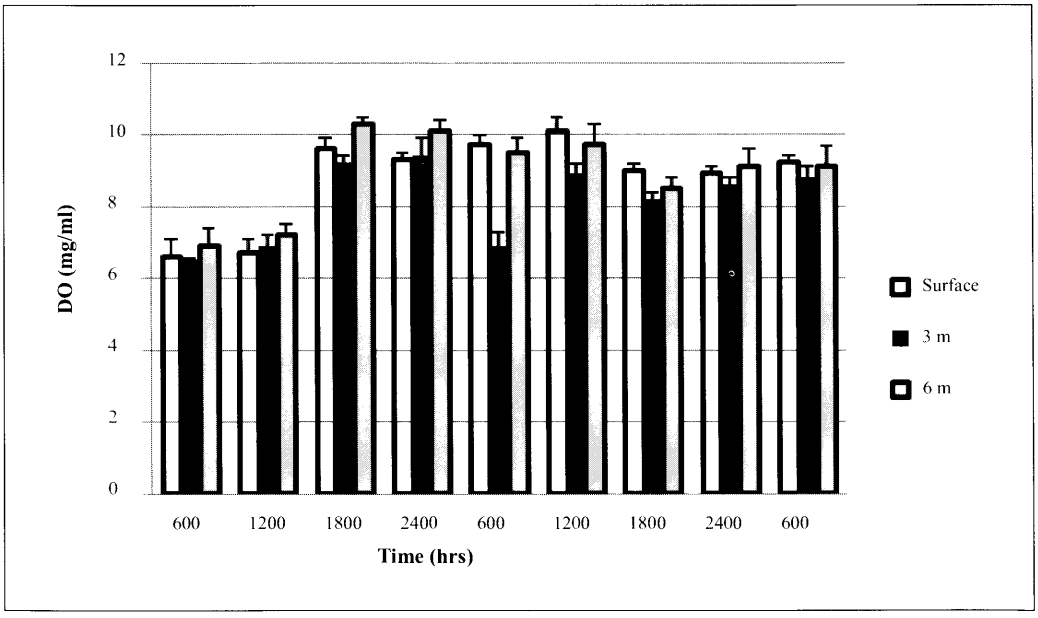


**Figure 3:** Variations in DO at surface, 3 and 6 m depths of Kenyir Lake during 48 hours of observation

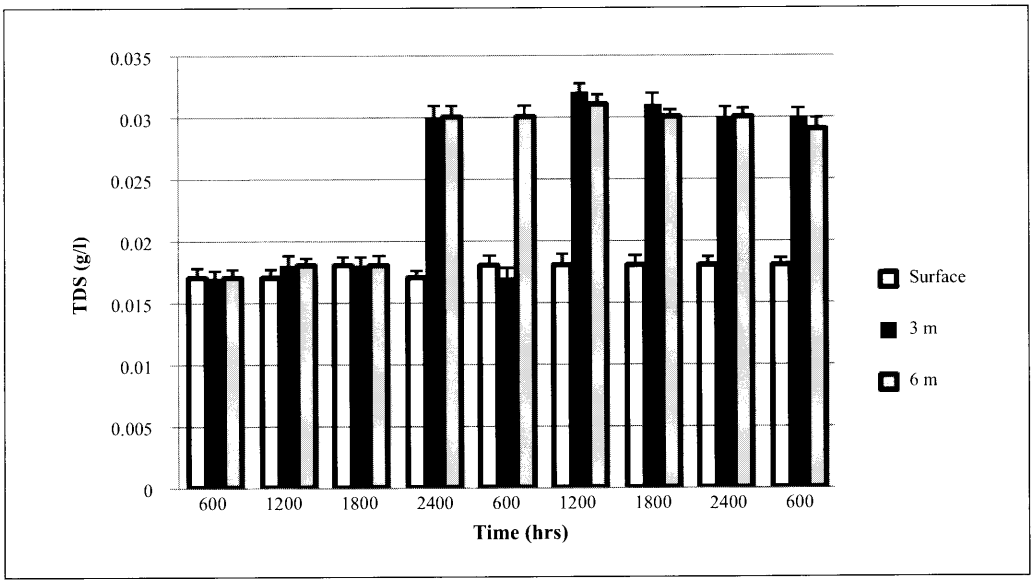


**Figure 4:** Variations in TDS at surface, 3 and 6 m depths of Kenyir Lake during 48 hours of observation

The productivity of Como region with respect to chlorophyll a at surface water, and at depths of 3 and 6 m were studied. At surface water, the chlorophyll a was 0.1038 µg/l at 1800 hrs where the minimum was 0.0075 µg/l at 2400 hrs with a variation of 92.7% during 48 hours. At 3 m depth, the maximum chlorophyll a value was 0.0699 µg/l at 1200 hrs whereas the minimum was 0.0015 µg/l at 0600 hrs with 97.8% fluctuation. At the depth of 6 m, the maximum chlorophyll a value was at 2400 hrs (0.0798 µg/l) and minimum was at 1800 hrs (0.0086 µg/l) with 89.2% variation (Fig. 5).

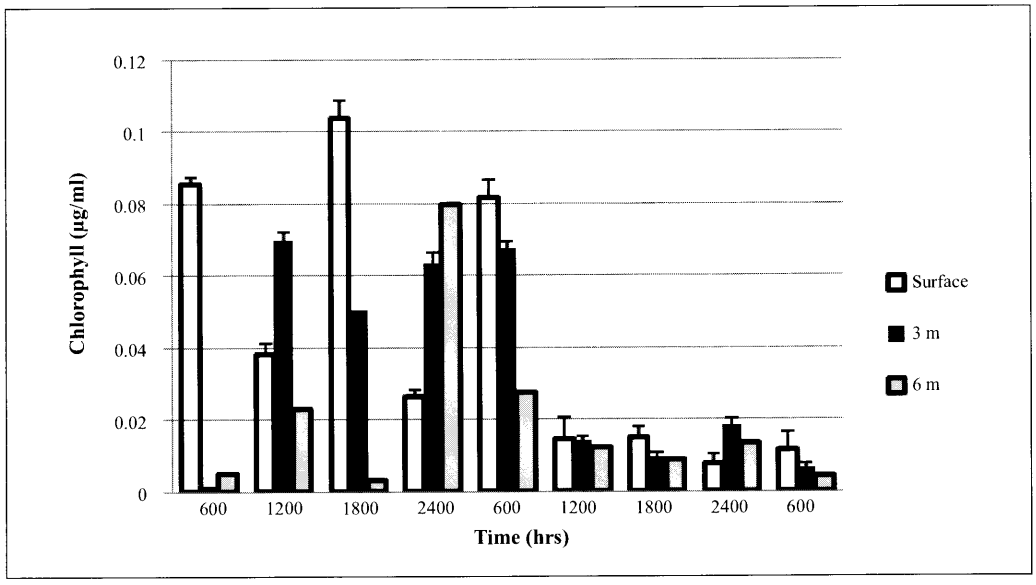


**Figure 5:** Chlorophyll *a* variations in surface, 3 and 6 m depths during 48 hours

The $H_2S$ contents were always below the detectable range in surface water. (Table1). At surface water, the nitrate and phosphate values were ranged from 0.16-0.70 µg/l and 0.06-2.30 µg/l respectively (Table 1). The $H_2S$, ($NO_3$) and ($PO_4$) contents at depth 3 m were; 1-1.6 µg/l, 0.26-0.50 µg/l and 0.01-0.09 µg/l respectively whereas at 6 m depth it ranged from 1-3.6 µg/l, 0.20-0.40 µg/l and 0.02-2.30 µg/l respectively (Table 1).

**Table 1:** Variations in $H_2S$, ($NO_3$) and ($PO_4$) contents during 48 hours

| | $H_2S$ (µg/ml) | | | $NO_3$(µg/l) | | | $Po_4$ (µg/l) | | |
|---|---|---|---|---|---|---|---|---|---|
| **Time** | **Surface** | **3 m** | **6 m** | **Surface** | **3 m** | **6 m** | **Surface** | **3 m** | **6 m** |
| 0600 | 0.6 | ND | 1.0 | 0.30 | 0.30 | 0.20 | 0.37 | 0.09 | 0.37 |
| 1200 | 0.1 | ND | 1.1 | 0.40 | 0.50 | 0.30 | 0.53 | 0.05 | 0.02 |
| 1800 | ND | 1.4 | 1.0 | 0.70 | 0.40 | 0.40 | 0.15 | 0.08 | 0.12 |
| 2400 | ND | ND | 2.1 | 0.20 | 0.30 | 0.20 | 0.08 | ND | 0.11 |
| 0600 | 0.6 | 3 | 1.0 | 0.20 | 0.26 | 0.20 | 0.07 | 0.07 | 0.03 |
| 1200 | ND | 1.6 | 3.6 | 0.16 | 0.36 | 0.36 | 0.06 | 0.01 | 0.20 |
| 1800 | ND | ND | 1.3 | 0.26 | 0.33 | 0.36 | 2.30 | 0.04 | 2.30 |
| 2400 | ND | ND | ND | 0.16 | 0.26 | 0.23 | 0.03 | 0.03 | 0.04 |
| 0600 | ND | 1.0 | 1.0 | 0.20 | 0.50 | 0.30 | 0.06 | 0.02 | 0.06 |

ND - not detected

## Discussion

The quality of lake's water and its ability to support fish is affected by the degree of diurnal mixing during the day and night times at all depths. The lake morphometry is the most important factors influencing mixing, though climate, lakeshore topography, inflow from streams, and vegetation also play an important role in determining the proper mixing of the lake water during day and night times. Chemical composition of an aquatic ecosystem consisting of various types of organisms, influences many micro level changes under different environmental conditions during day and night times. Diurnal variations in the physico-chemical characteristics of most of the lentic and lotic systems were thoroughly studied by several workers (Wiebe, 1929; Ganapati, 1955; George, 1961; George, 1966; Verma, 1969; Khan and Siddique, 1970; Saksena and Adoni, 1973; Vijayalaxmi and Venugopal, 1973; Mishra *et al.*, 1975; 1976; Wetzel, 1975; Bohra *et al.*, 1978; Kumar *et al.*, 1978; Rai and Dutta Munsi, 1979; Sahu *et al.*, 1995; Das *et al.*, 1997; Marshall, 1997; Jain, 1999). Diurnal fluctuations in abiotic factors have been shown to be the most strong and reproducible study which has been documented successfully in many streams and lakes (Scatena, 2001; Talling and Lemoalle, 2006). Diurnal cycles include ground-water exchange, temperature- and pH-dependent absorption reactions, precipitation and dissolution of solid phases, redox cycling and biotic uptake were the other studies carried out by several workers (Jones *et al.*, 2003). Diurnal variations in abiotic factors might fluctuate from low to high levels as observed by Shakar *et al.* (1993) at the Gupt-Ganga station of the torrential Neeru Nallah of Bhaderwah (Jammu) in India.

In an aquatic ecosystem, temperature is one of the most important ecological factors controlling the physiological behavior and distribution of organisms. Tockner *et al.* (1999) observed that temperature is one of the major determinant factors for assessing the conduciveness of the lake ecology. Jain *et al.* (1996) observed that diurnal variations in temperature in the Halai Reservoir of Vidisha in India influenced the aquatic life significantly. Temperature also influences the concentration of dissolved gases like $CO_2$, $O_2$ and chemical solutes of the water. In most of the lakes and streams, generally the water temperature has been found to be lower than the atmospheric temperature and temperature of the lake water varied with seasons. During the cold and monsoon seasons water temperature has been reported to be low due to frequent clouds, high humidity, high current velocity and high water level. Higher temperature regimes were observed during summer due to clear atmosphere, greater solar radiation and low water level. In Banjara

Lake (Swaranlatha and Narsing Rai, 1998) and Dahikhura reservoir (Yogesh Shastri and Pendse, 2001) have reported similar results in their studies. In our diurnal study, although in the morning (0600 hrs) and evening (1800 hrs), the air temperature was low (25-26°C), the temperature of the surface water and temperature up to 6 m depth was always higher (>30°C) (Fig. 1). This was an unusual observation recorded for the first time in Kenyir Lake. However, no such conditions were prevailing in Kenyir Lake as observed by other workers (Yusoff, 2007; Amal *et al.*, 2010). Similar conditions were found at 1200 hrs where variation in temperature was low both at the surface and in water column (3-6 m) (Fig. 1). Similarly, not much temperature differences were observed up to 4 m depth in Kenyir Lake during 2007-2008 by Amal *et al.* (2010). The highest surface temperature of the lake was 31.11°C during August (2007) whereas the lowest was 24.18°C during March (2008) up to 20 m depth. The natural water stratification and thermocline existed below 14 m depth of the lake during 2007 and 2008 (Amal *et al.*, 2010).

The pH of Kenyir Lake was constantly remained above 6.7. The maximum pH values were during the day time as compared to night time in both surface and depth up to 6 m. The higher values of pH recorded during day time could be attributed to increased in primary productivity wherein carbonates, sulfate, nitrates and phosphates are converted to hydroxyl ions (Wetzel, 1975). In earlier studies it has been observed that the range of pH of majority of the lakes and reservoirs lies between 6 and 9 (Wetzel, 1975). The lower pH during monsoon is due to high turbidity and decayed organic matters. However, in summers, the high temperature enhances microbial activity, causing excessive production of $CO_2$ and subsequently reduction in pH considerably. The pH of the Ramgarh Lake water in India was reported to be in the range from 6.8 to 8.5 which could be due to the high buffering capacity of the lake system (Chaturbhuj *et al.*, 2004). The pH of water has also been reported to be relatively high in winter and low in monsoon and summer months in some of the lakes. Maximum values reached to 8.5 in February due to high primary productivity and the lowest value (6.8) in the monsoon months in some of the lakes (Khan and Khan, 1985; Ghose and Sharma, 1988; Narayani, 1990).

DO is an important parameter of a lake which is essential to the metabolism of all aquatic organisms. Concentration of DO in water indicates its quality and relation to the distribution and abundance of various algal species. In the present study, DO was always higher (>6.5 mg/l) during 48 hours of observation time. The higher concentration of DO in water may be due to direct diffusion from the air and photosynthetic activity of autotrophs. Verghese *et al.* (1992) observed a strong correlation between pH and DO where lowering of pH consequently decreased the DO. Similar phenomenon was observed by Furtado *et al.* (1977) in Kenyir Lake where lower pH values were recorded when the DO contents were low in the water. The values of DO have also been found to be depleted during summers because at high temperature, the oxygen holding capacity of the water reported to be decreased considerably (Verghese *et al.*, 1992). The variety of biodegradable pollutants from domestic and industrial sources stimulates the growth of microorganisms which consume the DO (Verghese *et al.*, 1992; Yogesh Shastri and Pendse, 2001; Shanthi *et al.*, 2002).

Presence of TDS is influenced by the activity of plankton and organic materials. In many lakes, the TDS values of water samples have been observed to be within a range of 305 and 421 mg/l (Chaturbhuj *et al.*, 2004). The concentration of dissolved solids is high during monsoon, which could be due to addition of solids from the runoff water (Marker, 1977). In the present study the values of dissolved solids were high mostly during day time which is highly correlated with pH and dissolved oxygen ($P<0.05$) and could be due to high photosynthetic activity during day time.

High mortality of fishes, as reported by cage culturists of Kenyir Lake, was not due to the depletion of oxygen either during day or night hours or due to higher concentrations of any toxic materials as presumed by cage culturists. Most of the chemical parameters were far below the permissible concentration as prescribed by Boyd (1998) and as such these contents should not be harmful to fishes of Kenyir Lake. The productivity of the lake has also been found to be at the optimal level. Several studies have shown that higher diurnal variations in temperature dissolved oxygen, pH, conductivity and nutrients affect the lake environment considerably (Marshall, 1997). However, in the present study not much fluctuation in the temperature and DO was found at the surface and water up to a depth of 6 m. The main

cause of mortality and stress in cage grown fishes thus could be related to the temperature which has been observed to be always high and constant (~31°C). Secondly, due to higher stocking density and effective depth of ~2 m of the cages, the cage grown fishes get less space for their free movement which also causes considerable stress to the fishes. The limitation of depth of the cages restricts fishes for their free vertical movement which results in poor health condition. These conditions simultaneously promote outbreak of parasitic, fungal and bacterial diseases in cage grown fishes. Tilapia grown in cages at Como region has been found to be more susceptible to *Streptococcus agalactiae* infection as compared to fishes collected from some other lakes and regions (Amal *et al.*, 2010). The slow growth of the fishes as reported by the cage culturists could also be related to less feeding opportunities of the fishes inhabiting in the lake between 2 and 6 m depths which is a zone of higher temperature. These unsuitable environmental conditions are alarming which ultimately result in great loss of the fish stock and revenue to the farmers. Considering the seriousness of the situation, effective technology needs to be developed to make the cage culture practice more successful in Kenyir Lake after critically selecting suitable sites for the deployment of cages.

## Acknowledgements

The authors are also thankful to the Vice-Chancellor, University Malaysia Terengganu for providing facilities whereas (AC) is grateful to University for the award of a Principal Research Fellowship. The authors are also grateful to Nuinfra Aquaculture for providing logistic support for conducting the present studies.

## References

Amal, M.N.A., Zamri-Saad, M., Zulkafli, A.R., Siti-Zahrah, A., Misri, S., Ramley, B., Shahidan, H. and Sabri, M.Y. 2010. Water thermocline confirms susceptibility of tilapia cultured in lakes to *Streptococcus agalactiae*. *Journal of Animal and Veterinary Advances*, **9**: 2811-2817.

Bohra, O.P., Bhagat, M.J. and Iftakhar, M. 1978. Observations on diurnal variations in hydrobiological factors at Powai Lake, Bombay. *Comparative Physiology and Ecology*, **3**: 215-220

Boyd, C.E. 1998. Water Quality for Pond Aquaculture. Research and Development Series No. 43. International Center for Aquaculture and Aquatic Environments, Alabama Agricultural Experiment Station, Auburn University, Alabama.

Chaturbhuj, M., Sisodia, R., Kulshreshtha, M. and Bhatia, A.L. 2004. Case study of the Jamwa Ramgarh wetland with special reference to physico-chemical properties of water and its environs. *Journal of Environmental Hydrology*, **12**: 1-7.

Das, J., Das, S.N., and Sahoo, R.K. 1997. Semidiurnal variation of some physicochemical parameters in the Mahanadi estuary, east coast of India. *Indian Journal of Marine Sciences*, **26**: 323-326.

Ghose, N.C. and Sharma, C.D. 1988. Effect of drain water on the physico-chemical and bacteriological characteristic of river Ganga at Patna, Bihar. *In:* Trivedy, R.K. (ed), Ecology and Pollution of Indian Rivers. Asian Publishing House, New Delhi, pp. 255-269.

Furtado, J., Soepadmo, I.E., Sasekumar, A., Lim, R.P., Ong, S., Davidson, S.L. and Liew, K.S. 1977. Ecological effects of the Terengganu hydro-electric project (Kenyir Project). Wallaceana, Suppl. 1, p. 51.

Ganapati, S.V. 1955. Diurnal variations in dissolved gases, hydrogen ion concentration, some of the important dissolved substances of biological significance in three temporary rocky pools in stream bed at Mettur Dam. *Hydrobiologia*, **7**: 285-303.

George, M.G. 1961. Diurnal variations in two shallow ponds in Delhi, India. *Hydrobiologia*, **18**: 265-273.

George, M.R. 1966. Diurnal variation in physico-chemical factors and zooplankton in the surface layer of three fresh water fish ponds. *Indian Journal of Fisheries,* **13**: 48-82.

Jain, S.M., Sharma M. and Ramesh, T. 1996. Seasonal variations in physico-chemical parameters of Halai reservoir of Vidisha district, India. *Indian Journal of Ecobiology*, **8**: 181-188.

Jain, Y. 1999. Studies on diel variations in some water quality parameters at the time of immersing idols at Hanumantal Lake, Jabalpur (MP), India. *Journal of Environmental Pollution,* **6**: 95-104.

Jones, C.A., Nimick, D.A. and Mccleskey, R.B. 2003. Relative effect of temperature and pH on diel cycling of dissolved trace elements in prickly pear creek, Montana. *U.S.A. Geological Survey*, pp. 5.

Khan, A.A. and Siddigue, A. 1970. Diurnal variation in the pond moat at Aligarh. *Journal of Inland Fisheries Society of India,* **2**: 146-154.

Khan, I.A. and Khan, A.A. 1985. Physico-chemical conditions in Seikha Jheel at Aligarh. *Journal of Environment Ecology*, **3**: 269-274.

Kumar, J.K., Khan, M.N., Aziz, H.M. and Mahammad, M. 1978. Observation in diurnal variation in hydrobiological condition in two fish ponds of Hyderabad, India. *Comparative Physiology and Ecology*, **3**: 111-114.

Marker, A.F. 1977. The benthic algae of some streams in southern England. *Journal of Ecology*, **65**: 223-235.

Marshall, B.E. 1997. Lake Chivero after forty years: the impact of eutrophication. *In*: MOYO, N.A.G. (ed.) Lake Chivero. A Polluted Lake. University of Zimbabwe Publications, Harare, 1-12.

Mishra, S.D., Bhargave, S.C. and Bohra, O.P. 1975. Diurnal variations in physicochemical factors at Padamsagar reservoir during premonsoon period of year 1974. *Geobios,* **2**: 32-33.

Mishra, S.D., Bhargave, S.C. and Bohra, O.P. 1976. Diurnal variations in certain hydrobiological factors and phytoplankton pigments at Padamasagar reservoir, Jodhpur (Raj.), Proceeding Semiarid Desert Technology, Jodhpur Trans (Aug. 1974). *Indian Societal Desert Technology,* **1**: 18-19.

Narayani, N. 1990. Seasonal changes in abiotic parameters of eutrophic wetlands (lower lake, Bhopal). *In*: Shukla, A.C., Vandana, A., Trivedi, P.S. and Pandey, S.N. (Ed.). Advances in Environmental Biopollution. A.P.H. Publishing Corporation, New Delhi, 155-163pp.

Nimick, D.A., Cleasby, T.E. and Mcleskey, R.B. 2005. Seasonality of diel cycles of dissolved trace metal concentrations in a rocky mountain stream. *Environmental Geology*, **47**: 603-614.

Parsons, T.R., Maita, Y. and Lalli, G.M. 1984. *A Manual of Chemical and Biological Methods for Seawater.* Pergamon Press, 173 p.

Rai, D.N. and Dutta Munsi, J.S. 1979. Observation on diurnal changes of some physico-chemical factors of three tropical swamps of Darbhanga (North Bihar), India. *Comparative Physiology and Ecology,* **4**: 52-55.

Rouf, A.J.M. Abdur, Phang Siew-Moi, and Ambak, Azmi, M. 2010. Depth distribution and ecological preferences of periphytic algae in Kenyir Lake, the largest tropical reservoir of Malaysia. *Chinese Journal of Oceanology and Limnology*, **28**: 856-867.

Sahu, B.K., Rao, R.J. and Behera, S.K. 1995. Studies on some physicochemical characteristics of the

Ganga river water (Rishikesh, Kanpur) within twenty four hours sluring winter 1994. *Eco Environmental Conservation,* **1**: 35-38.

Saksena, S.B. and Adoni, A.D. 1973. Diurnal variation in Sagar Lake, Sagar, India I. Studies in deep water area. *Hydrobiologia,* **43**: 535-543.

Scatena, F.N. 2001. Ecological rhythms and the management of humid tropical forests. Examples from the Caribbean Forest, Puerto Rico. *Forest Ecology and Management*, **154**: 453-464.

Shanthi, K., Ramasamy, K. and Lakshmanaperumalsamy, P. 2002. Hydro biological study of Siganallur lake at Coimbatore, India. *Journal of Nature Environment and Pollution Technology*, **1**: 97-101.

Shakar, C., Malhotra, Y.R. and Datta, S.P.S. 1993. Daily variation in some abiotic parameters of water at Gupt Ganga station of torrential Neeru Nallah, Bhaderwah (Jammu). *Journal of Nature Conservation*, **5**: 51-58.

Swaranlatha, N. and Narsing Rai, A. 1998. Ecological studies of Banjara Lake with reference to water pollution. *Journal of Environmental Biology*, **19**: 179-186.

Talling, J. and Lemoalle, J. 2006. Ecological dynamics of tropical inland waters. Cambridge University Press. 441p.

Tockner, K., Malard, F. and Ward, J.V. 1999. An extension of the flood pulse concept. *Hydrological Proceedings*, **14**: 2861-2883.

Verghese, M., Anil, C. and Naik, L.P. 1992. Hydrobiological studies of a domestically polluted tropical pond. I. Physico-chemical characteristic. *Journal of Pollution Research*, **11**: 95-100.

Verma, M.N. 1969. Diurnal variation in a fish pond in Seoni, India. *Hydrobiologia,* **30**: 129-137.

Vijayalaxmi, G.S. and Venugopal, V.K. 1973. Diurnal variation in the physicochemical and biological properties in velar estuary. *Indian Journal of Marine Science,* **2**: 19-22.

Wetzel, R.G. 1975. Limnology. W. B. Saunders Co., Philadelphia, U.S.A. 743p.

Wiebe, W.H. 1929. Diurnal variations in the amount of dissolved oxygen, alkalinity, and free ammonia in certain fish ponds at Fairport, (Lowa). The Commissioner of U.S. *Bureau of Fisheries*, **31**: 120-126.

Yusoff, F.M. and Lock, M.A. 1994. Thermal stratification and its role in controlling eutrophication in a tropical reservoir, Malaysia. Proceedings of the International Tropical Limnology Conference, Indonesia.

Yusoff, F.M. 1996. Environmental management of Kenyir Lake, Malaysia: Prevention of eutrophication. *Journal of Ensearch,* **9**: 43-48.

Yusoff, F.M. 2007. Taski Kenyir. Thermal stratification and its implications on sustainable management of the reservoir, Paper presented at the colloquium on Lakes and Reservoirs Management: Status and Issues 2-3 August 2007, Putrajaya Malaysia

Yusoff, F.M., Matias, H.M. and Khan, A. 2002. Changes of water quality, chlorophyll a and zooplankton along river-lacustrine continuum in a tropical reservoir, Verh. *International Verein, Limnology*, **28**: 295-298.

Yogesh, S. and Pendse, D.C. 2001. Hydro biological study of Dahikhura reservoir. *Journal of Environmental Biology*, **22**: 67-70.