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Water Quality Characterisation and Restoration Measures of University of Nottingham Malaysia Campus (UNMC) Lake

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Abstract

Nutrient enrichment has been identified as the major cause of University of Nottingham Malaysia Campus (UNMC) Lake's water quality degradation. This study critically examines the nature, source and delivery of nutrients into the lake and observes that uncontrolled anthropogenic activities along the catchment area are the major sources. The chemical analyses of the water samples drawn from different sampling points were carried out in the laboratory and the total phosphorus readings were in the range of 20 to 55.7 µg/L with the inflow 1 recording the highest level. The chlorophyll a concentrations in the lake water were between 39 to 65 µg/L which exceeded Malaysian water quality standard. However, the silicate and nitrate levels were found to be in lower concentrations. Dissolved oxygen and pH readings obtained through *in situ* measurements in the lake water showed that there was oxygen depletion in the water during the night while it increased during the day, also the lake was acidic in the night and became alkaline in the day. All the findings were integrated to draw realistic restoration goals for the lake.

Keywords

Lake, Water Quality, Nutrient Enrichment, University of Nottingham, Restoration, Drainage, Chlorophyll, Malaysia

1. Introduction

Proponents of Lake Anita story claims, "lakes with better water quality contribute to a higher quality of life, local economic development and increased property values for people". However, urbanization has introduced

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changes in climatic conditions such as higher temperature in the cities compared with their rural surroundings [1], hence the creation of most urban/artificial lakes for relaxation, beautification, and recreational activities among other uses for the people. It offers the ideal location for improvement of human psychological wellbeing [2]. However, anthropogenic activities around catchment area of a lake, which produce pollutants like-fertilizers, pesticides, oil and grease, animal and human wastes, lead to deterioration of its water quality which in turn affects its various functions. In addition, some factors like the origin, source of water, location and usage of a particular lake make it unique in terms of its physical, chemical and biological characteristics. Due to these factors, the problems of lakes differ and must be solved based on the particular case [3]. Best management practices around the watershed are also very necessary in controlling pollution of lakes from non-point sources [4].

The use of restoration as a means of preserving the quality of water in lakes is important as it helps to return them closer to the ecosystem's natural conditions because it is difficult to bring them back to pristine condition once degraded. Several projects over some decades have been used to solve this anthropogenic challenge of pollution. This practice has a strong leadership amongst lake managers in the United States of America, especially in the state of Florida. However, in many other parts of the world critical goals, criteria and protocols on lake restoration are yet to be mainstreamed.

Physical and chemical analyses of the lake and comparisons of the results with National standards are important problem identification methods which help to establish the main causes of the lake problem. This is the first step in restoration process [3] [5]. This paper therefore tries to identify the nutrient sources, nature and delivery into the lake; ascertain the chlorophyll a concentration levels in the lake; and to determine realistic restoration goals for the Lake.

The Study Area and Sites

The study site is the University of Nottingham Malaysia Campus (UNMC) Lake, located at Semenyih in the State of Selangor of Malaysia. It is basically an artificial, shallow lake with the deepest point of about 2.2 meters and total area of 20,480 m^2 which lies within the coordinates of 02.94557N and 101.87337E. The lake serves as the icon of the campus which is mostly used by the Marketing Department in most of their promotional items to project the image of the campus to the world. It is also a landmark/identity for all the three University of Nottingham campuses (UK, China and Malaysia). It is situated right in between the main gate and the Trent building where its aesthetic appeal is so apparent to all driving into the campus. Apart from its aesthetic purpose, the lake serves other purposes to both students and staff such as jogging and other physical activities, relaxation, meditation, reading and strolling. There are three inflows that supply water to the lake and one outflow that discharges excess water from the lake. It also has two aerators for beautification and air circulation. The only source of water recharge for the lake is runoff from the catchment area which is about 101 acres. Each inflow has a pollutant trap that gets rid of debris from runoff before draining into the lake.

The University Lake just like any other water body significantly contributes to the ecology and the general ecosystem of the catchment. The determination of the water quality of the lake, and the development of protocols for its restoration would have helped to achieve an ideal situation not only for UNMC but other actors and inhabitants within the periphery. Therefore this study's contribution to knowledge in lake restoration, environment and literature is worthy. Appropriate recommendations would be made available to UNMC and the local government in charge for decision making.

The lake drainage map was used to identify the inflows and outflow. The sampling sites were divided into six and coded as follows: main lake 1 (ML1), main lake 2 (ML2), main lake inflow 1 (MLI1), main lake inflow 2 (MLI2), main lake inflow 3 (MLI3), and main lake outflow (MLO) as shown in **Figure 1**. The inflow water samples were analyzed to determine the amount of nutrients entering into the lake and the amount going out was determined from the outflow samples while the lake water showed the amount of nutrients available for algal uptake. The code ML stands for main lake which was purposely used for this study to identify the study site. The main lake 1 and 2 points were marked at the nearest deepest points (2.2 m) at both sides of the lake and buoys were deployed ahead of sampling to indicate the sampling points for the two sides.

2. Methodology

A toolbox containing the following items: waterproof notebook, sharpened pencils, scissors, marker pens, echo sounder, and 3 m tape measure was neatly packed prior to each sampling day. Other pieces of field kit such as

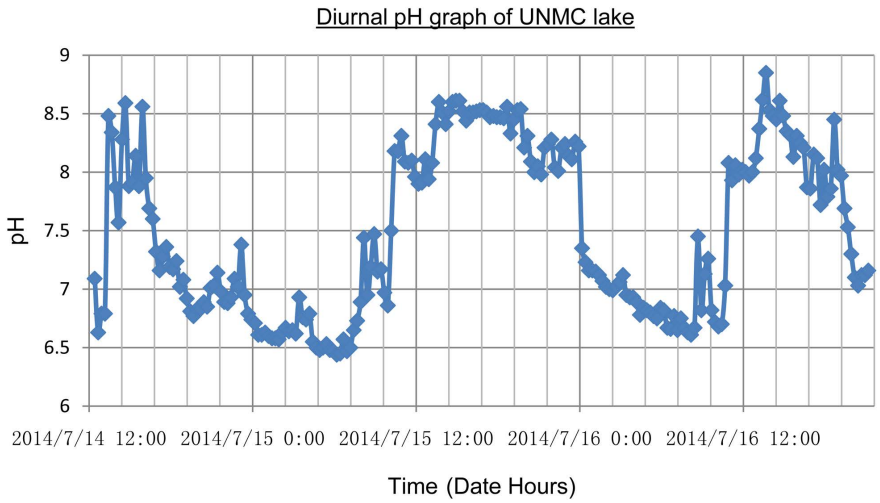

Figure 1. Diurnal pH graph of UNMC lake.

pumped-up boat, boat oars, lifejackets, buckets, curly weighted tube, secchi disk, probe with depth-marked rope and carabiner were also assembled ahead of sampling days. Laboratory equipment used include; spectrophotometer, filtration unit, centrifuge, pressure cooker, hotplate, refrigerator and weighing machine. Others include 4 cm and 10 cm glass cuvettes, 50 ml and 100 ml conical flasks, spatulas, 15 ml centrifuge tubes, tweezers, aluminium foil, scissors, Pasteur pipettes (1, 5 and 10 ml), measuring cylinders (25, 50, 100 and 200 ml), beakers (50, 100 and 250 ml), volumetric flasks (50, 100 and 250 ml), test tubes and rack, autoclave tape and 30 ml Nalgene bottles. Distilled water was in constant supply from the laboratory.

The lake water samples were collected using the clean weighted curly tube to take a mixed water sample down the depth of the water column and care was taken not to hit and sample the mud from the lake bottom. The water sample was further transferred into the clean, labeled sample bottles after rinsing them with the water. The inflows and outflow were sampled by pointing the sample bottles upstream. The sample bottles were thoroughly rinsed respectively with water from each sampling point and placed as deep as possible in the inflows to avoid sampling the mixed up water from the lake. Proper care was also taken not to sample already disturbed sediment from the outflow. All the sample bottles were filled to the top to exclude air and capped securely. The weather conditions for each sampling day were recorded.

Sample Analyses

The dissolved oxygen concentrations, pH, and temperature readings were taken weekly at 50 cm depth intervals down the water column *in situ* with a probe which its wire had previously been marked and readings recorded in a waterproof notebook. Care was taken not to allow the probe to be immersed in the sediment. The secchi disk attached to a marked rope was used to measure the secchi depth. The depth at which the disk was no longer visible and the depth at which it reappears were recorded and the average of the two taken as the secchi depth. This determines the level of clarity of the lake water. Chlorophyll a, Total Phosphorus, Soluble Reactive Phosphorus, Nitrate and Silicate were measured in the Laboratory using Standard methods.

3. Results and Discussion

3.1. Ecological Status of UNMC Lake

The diurnal pH of the lake (**Figure 1**) below indicates that in the daytime, the lake's pH readings increased to about 8.8 and dropped massively during the night to about 6.5.

The graph below (**Figure 2**) shows the daily reading of dissolved oxygen in the lake for two days. The pattern shows that the lake has highest concentration of dissolved oxygen (90%) during the day which drops drastically in the night to as low as 30%.

The massive drop in both pH and dissolved oxygen can be explained by the high productivity of the lake. [6]

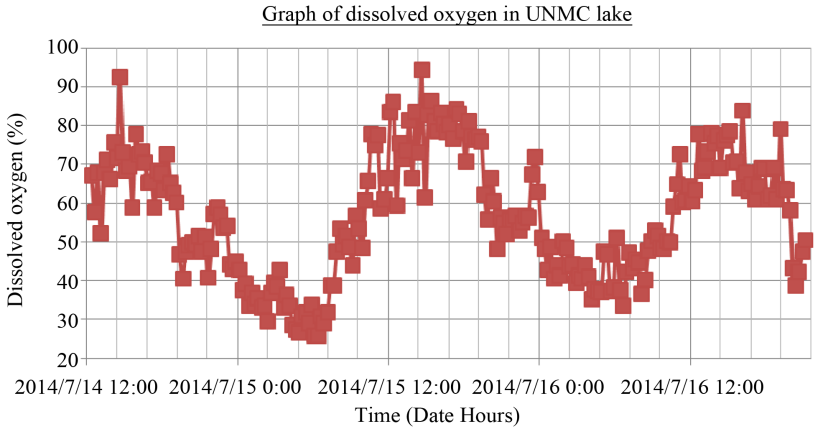

Figure 2. Diurnal dissolved oxygen level in UNMC lake.

identified photosynthesis of algae and respiration as the two key components for oxygen consumption and production in lakes. The algae produce oxygen during the process of photosynthesis in the day thereby increasing the dissolved oxygen in the water while during respiration in the night, dissolved oxygen is used up by aquatic organisms and fish causing oxygen depletion as can be seen in the graph. Bacteria and microbes also utilize dissolved oxygen in decomposition of dead algae and other organic materials [7]. Algae and other plants use carbon dioxide (a weak acid) during photosynthesis thereby resulting in the alkalinity of the lake in the day time. On the other hand, the process of respiration has carbon dioxide as a by-product which increases the acidity of the lake [7]. The rapid drop in the readings indicates an algal bloom which might be the cause of fish kills in the lake, a problem fairly common in tropical lakes [8]. The temperature readings in the lake varied between 29.1˚C and 30.7˚C with the surface of the lake recording highest values and the bottom with lower values. Regulation of body temperature of aquatic animals under this condition will be difficult.

The secchi depth readings are shown in **Table 1** with ML2 recording highest value of 0.65 m on the first week of sampling and lowest value of 0.42 m on the last week of sampling. ML2 also has its highest value (0.615 m) on the second week while its lowest was on the first week (0.47 m). The secchi depth readings when compared to the depth of the lake (2.2 m) could be said to be high. [9] stated that secchi depth could be used to estimate the amount of algae in the water which affect water clarity and light penetration.The lake can hence be said to be turbid which affects the extent of sunlight penetration into the lake which subsequently affects photosynthesis [4], as well as the aesthetic appeal.

Malaysian lake water quality standard for chlorophyll a is 0.7 µg/L while UNMC Lake recorded the range of 19.3 to 65.9 µg/L (**Figure 3**) during the study period. This far exceeded the acceptable limit for lake water in Malaysia and hence can be said to be eutrophic. This can be linked to the excessive algal bloom going on in the lake since chlorophyll a is a measure of algal biomass in lake water [10] [11] and commonly used to measure the level of water clarity with high level indicating poor water quality while low level indicates good water quality. Higher chlorophyll a levels are common during the summer period with high temperature and light intensity. The excessive level of chlorophyll in UNMC Lake can be linked to the nutrient (phosphate) loading in the lake water which the algae utilise to grow and multiply. This can be attributed to the fact that runoff from the catchment area of the lake are discharged into the lake without control. Moreover, the study period was during summer when there is higher level of algal bloom in lakes due to the warmer temperature reading (29˚C to 30.7˚C) that promotes photosynthesis which is a process by which the algae (plants) manufacture their food.

[12] classified lakes with phosphorus concentrations below 0.01 mg/L as oligotrophic; those between 0.01 and 0.02 mg/L as mesotrophic while those exceeding 0.02 mg/L are eutrophic. On the other hand, comparing the results with this classification, UNMC Lake can be said to be eutrophic. High phosphorus concentration in water causing eutrophication prevents lakes from attaining good ecological status [13]. The range of soluble reactive phosphate levels in the UNMC Lake is between 0.006 to 0.009 mg/L in all the sampling points with the inflow 1 (MLI1) recording the highest value of 0.009 mg/L (**Figure 4**). From the study by [14], it was indicated that in some instances, trace amounts of dissolved phosphate in lake water are enough for high productivity of algae. This justifies the reason for the algae growth in the lake. The source of the phosphorus could be from runoff

Table 1. Secchi depth readings (m).

	30/6/2014	7/7/2014	14/7/2014	21/7/2014	30/7/2014	6/8/2014	14/8/2014
ML1	0.47	0.615	0.57	0.514	0.475	0.490	0.510
ML2	0.65	0.51	0.61	0.515	0.48	0.51	0.420

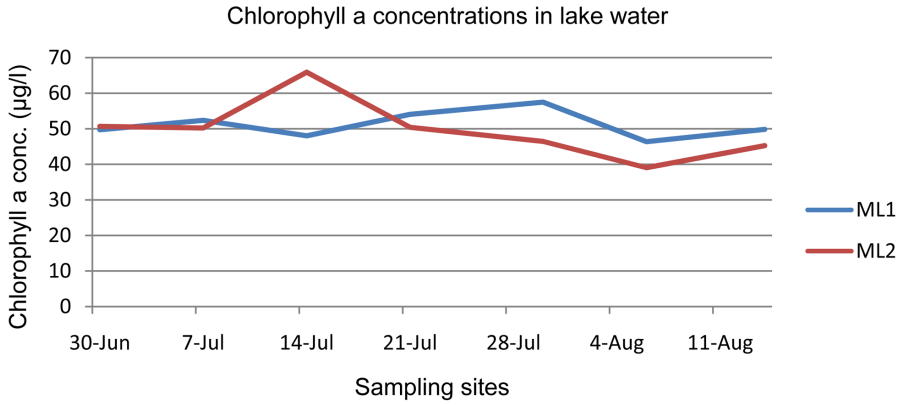

Figure 3. Chlorophyll a concentrations in Main Lake 1 and 2.

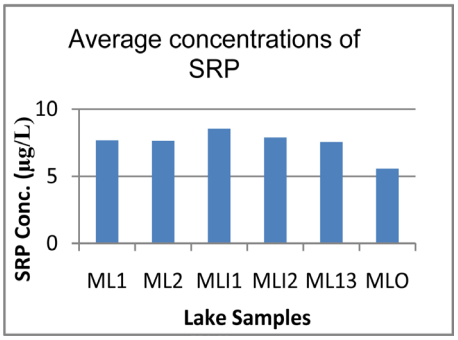

Figure 4. Average conc. of soluble reactive Phosphate.

from the lake catchment. It was observed that there is no management control of the nutrient richness of the discharge water going into the lake. When it rains, runoff from the different areas of the Campus rich in various nutrients such as pesticides, fertiliser, soaps, detergent and animal manure all drain into the lake thereby enriching it [15]. This can be justified by comparing the phosphorus concentration level of MLI1 which is the major inflow to the lake to other sampling points. It recorded the highest average value of 56.7 µg/L (0.0567 mg/L). MLI2 and MLI3 also recorded high concentrations while the outflow was the lowest (**Figure 5**).

Dissolved silicate was found to be in lower levels in all the sampling points when compared to Malaysian Water quality standard although the MLI3 recorded the highest concentration indicating that nutrients are entering the lake through this point. Silicate is needed more by diatoms than by other phytoplanktons in water bodies for build-up of their skeletal structures [16] and water with lower concentration of silicate indicates larger presence of flagellates. The concentration values of silicate in all the sampling points range between 1.2 to 3 mg/L (**Figure 6**).

The nitrate concentration recorded in the study is very low compared to the National Standard. This suggests that phosphorus is the element controlling algal growth in UNMC Lake while nitrogen is rarely the limiting nutrient. According to [10] [17], lakes surrounded by rich phosphate deposits and phosphorus-containing soil may be nitrate-limited and in such circumstance chlorophyll a and phosphorus are the independent variables for algal biomass estimation. [17] identified that most cyanobacteria can fix atmospheric nitrogen to form biological available nitrate and can favourably compete at lower concentration of nitrate in the water. The study by [10] suggests that phosphorus is the limiting nutrient for lakes with total phosphorus below 0.1 mg/L while nitrogen

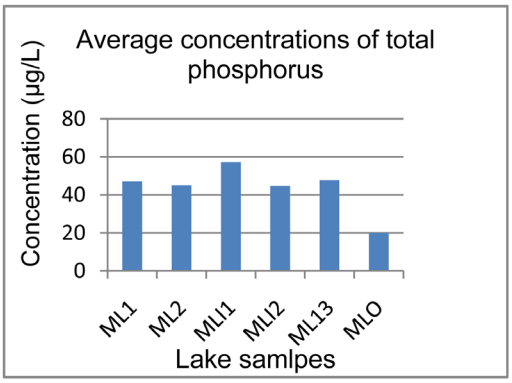

Figure 5. Average conc. of nitrate.

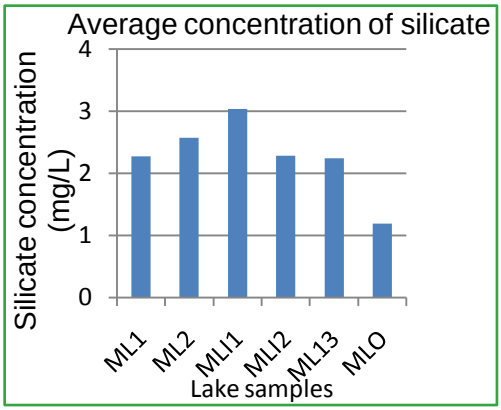

Figure 6. Average silicate concentration.

is the limiting nutrient for those above that concentration and this reconciles the low nitrate levels recorded in UNMC Lake considered to be eutrophic since the total phosphorus levels are below 0.1 mg/L in all sampling points. MLI3 has the highest concentration than all other sampling points indicating it is a nutrient-entry point (**Figure 7**).

3.2. Restoration Measures for University of Nottingham Malaysia Campus (UNMC) Lake

Having identified University of Nottingham Malaysia Campus Lake's problems through the physical and chemical analyses carried out during the course of this study which is the initial step that must be followed before restoration goals are developed [3] [5], attention must now be paid on using the results obtained to draw effective restoration measures suitable for the lake [3]. Since there is no single restoration technique used in effective restoration of lakes according to [3] [18], successful shallow lake management strategies comprising of different realistic restoration methods which include 1) in-lake treatment measures- physical, chemical and biological measures 2) watershed management techniques to reduce nutrient influx into the lake, would therefore be employed to effectively bring the lake to good environmental quality that would be appealing to the users. However, the cost implication of each method is fully considered.

There should be a detention tank to collect runoff from the catchment areas where the water should be filtered and treated to reduce the nutrient load before being discharged into the lake. In addition, there should be strict adherence by the cafeteria staff to make use of oil/grease trap and its regular clean-up and maintenance. It was observed that left over oil is directly poured into the drainage and goes straight to the lake hence the cause of the fish kills witnessed on the lake last few months. To avoid future occurrence of this, the staff must undergo trainings to know the consequences of their actions and proper supervisory monitoring team set up to enforce adherence to it.

Sedimentation as a result of construction works going on around the catchment area is another major factor to

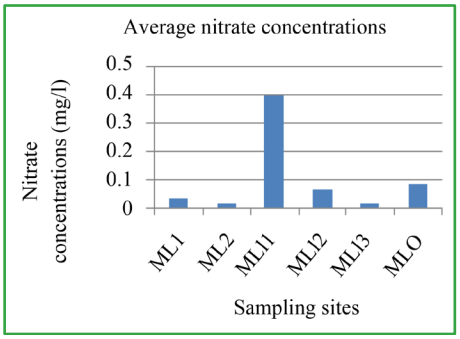

Figure 7. Average nitrate concentration.

lake water deterioration. The sediments are introduced into the lake increasing its turbidity and phosphorus load. The detention tank will also take care of this problem by allowing only treated water to enter into the lake.

Wetland construction along the lake shoreline is another restoration measure that could be applied on UNMC Lake. Native Malaysian plants such as *Lepironia*, *Phragmites and Eriocaulon* species should be planted in separate cells at the inflow points of the lake which would help to filter the nutrients and sediments from runoff. It will also help in the breakdown of the nutrients through bio-chemical processes. The wetland will also serve as an attraction for wildlife such as monitor lizard, ducks, swans and kingfishers thereby increasing the species richness of the lake which would be very useful for research and recreational purposes to both students and staff. It can also be used as picnic front for students and staff. This wetland construction measure was applied in Putrajaya Lake to increase its water quality [19].

For effective and long term restoration of the Lake, there should be establishment of lake monitoring and management body whose functions would include the following: 1) to regulate the watershed activities such that reduced or no nutrient should be introduced into the lake. This can be achieved by regulating the frequency and amount of fertilizer used by the estate department on the lawn, ensuring that all the sewage water is channelled to the treatment plant; ensuring that used water from the halls, cafeteria, laboratories is channelled into a detention tank for treatment before entering the lake; ensuring that the cafeteria staff do not pour used oil directly into the drains rather into the oil/grease trap; controlling the amount of sediments from the construction sites and other areas by making sure the water passes through detention tank and wetland (when constructed) and monitoring the maintenance of the drainage 2) Education of the general public should be another function of the lake governing body. The stakeholders should be educated on the importance of good lake watershed management practices and its contribution to water quality management. The cafeteria staff should be continuously trained on the implication of introducing oil and other organic matters into the lake which promote fish kills. Furthermore, the estate staff should be trained on how to use minimal amount of fertilizers and pesticides on the catchment area. Combination of governance and education would lead to positive change in land management practices which would eventually reduce the nutrient input into the lake and further promote the water quality. The lake team should continuously monitor water quality of UNMC Lake. Lake restoration is not a final stage in lake management rather continuous monitoring must be in place to serve as a guide to know when the water quality is going down and the cause for it. Since the lake is an iconic image of the campus, proper care must be taken to keep it in its best shape always in order to effectively satisfy its various users.

4. Conclusions

This study has been successfully carried out to identify problems causing the water quality degradation of the University of Nottingham Malaysia Campus, sources and nature of delivery of pollutants into the lake. High nutrient loads in the lake water which promote algal bloom are introduced from the catchment area of the lake due to uncontrolled anthropogenic activities going on around it. This led to reduction in its water clarity and colour thereby affecting its different uses. The lake was found to deviate from Malaysian National Water Quality Standard in some parameters like chlorophyll a, dissolved oxygen and total phosphorus concentrations due to high productivity nature of it.

Finally, realistic restoration measures were carefully drawn to restore the lake to a better environmental condition suitable for all uses putting the cost implications into considerations. Some recommendations were also

suggested to the management of University of Nottingham Malaysia Campus for sustainable management of the lake and its catchment area.

5. Recommendations

In order to maintain the University Lake in a good environmental condition, the following recommendations were made to the management as some of the outcomes of the study. There should be establishment of lake monitoring and management team made up of lake management experts whose job would be to continuously monitor the lake's water quality through laboratory analyses and physical measurement in comparison with Malaysia Water Quality Standards. This would help reduce any deviation from the standards and the causes easily traced and restored. New studies should be carried out on the lake from different viewpoints such as: establishing the major causes of fish kill experienced in the lake; determining if there is internal loading of phosphorus from the sediments. This would help to prevent future degradation of the lake and also provide more scientific database on the Nottingham Malaysia Lake for reference and research purposes in future.

Regular watershed management training should be given to all involved in any form of activities on the catchment area of the lake. Grease traps and pollutant traps should be frequently checked and maintained properly to ensure their effectiveness. Monitoring and enforcement should also be applied for compliance to the best management practices on the watershed.

The drainage system should be re-checked to ensure that sewage and cafeteria waste water are not finding their way into the lake. The runoff should also be treated to reduce the nutrient level in accordance to the Malaysian National Water Quality Standards before being discharged into the lake. More recreational activities and features should be introduced and proper monitoring and regulation should be in place to ensure their proper uses and safety for all which would help to promote good water quality for the lake.

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References

[1] Amparo, M. and Ernesto, J. (2000) On the Environmental Role of Urban Lakes in Mexico City. *Urban Ecosystems*, **4**, 145-166. http://dx.doi.org/10.1023/A:1011355110475

[2] Rabiatul, A.N., Sabarinah, S.A. and Azni, Z.A. (2012) Adaptive Outdoor Thermal Comfort at an Urban Park for the Benefit of the Present and Future Community. *Procedia-Social and Behavioural Sciences*, **68**, 865-878.

[3] United States Environmental Protection Agency (1973) Measures for the Restoration and Enhancement of Quality of Freshwater Lakes.

[4] Ashraf, M.A., Maah, M.J. and Yusoff, J. (2010) Water Quality Characterization of Varsity Lake, University of Malaya, Kuala Lumpur, Malaysia. *E-Journal of Chemistry*, **7**, S245-S254.

[5] Hilt, S., Gross, E.M., Hupfer, M., Morschield, H., Mahlmann, J., Melzer, A., Poltz, J, Sandrock, S., Scharf, E., Schneider, S. and Weyer, K. (2006) Restoration of Submerged Vegetation in Shallow Eutrophic Lakes—A Guideline and State of the Art in Germany. *Limnologica*, **36**, 155-171. http://dx.doi.org/10.1016/j.limno.2006.06.001

[6] Urban, N.R., Apul, D.S. and Auer, M.T. (2004) Community Respiration Rates in Lake Superior. *Journal of Great Lakes Research*, **30**, 230-244. http://dx.doi.org/10.1016/S0380-1330(04)70388-3

[7] Jones, R. (2011) Oxygen—The Most Important Water Quality Parameter? *Water Column*, **23**, 1-6.

[8] Ochumba, P.B.O. (1990) Massive Fish Kills Within Nyanza Gulf of Lake Victoria, Kenya. *Hydrobiologia*, **208**, 93-99. http://dx.doi.org/10.1007/BF00008448

[9] Carlson, R.E. and Simpson, J. (1996) A Coordinator's Guide to Volunteer Lake Monitoring Methods. North American Lake Management Society, 96 p.

[10] Stanley, C.D., Clarke, R.A., McNeal, B.L. and MacLeod, B.W. (2003) Relationship of Chlorophyll a Concentration to Seasonal Water Quality in Lake Manatee, Florida. http://edis.ifas.ufl.edu

[11] Bachmann, R.W., Hoyer, M.V. and Canfield, D.E. (2003) Predicting the Frequencies of High Chlorophyll Levels in Florida Lakes from Average Chlorophyll or Nutrient Data. *Lake and Reservoir Management*, **19**, 229-241. http://dx.doi.org/10.1080/07438140309354088

[12] Murphy, S. (2007) General Information on Phosphorus. City of Boulder/USGS Water Quality Monitoring (Online). http://bcn.boulder.co.us/basin/data/NEW/info/TP.html

[13] Duethmann, D., Anthony, S., Carvalho, L. and Spears, B. (2009) A Model-Based Assessment of Non-Compliance of Phosphorus Standards for Lakes in England and Wales. *International Journal of River Basin Management*, **7**, 197-207. http://dx.doi.org/10.1080/15715124.2009.9635383

[14] Baldwin, D.S., Whittington, J. and Oliver, R. (2003) Temporal Variability of Dissolved P Speciation in a Eutrophic Reservoir—Implications for Predicting Algal Growth. *Water Research*, **37**, 4595-4598. http://dx.doi.org/10.1016/S0043-1354(03)00403-2

[15] United States Environmental Protection Agency (2014) (Online). http://www2.epa.gov/nutrientpollution/effects.html

[16] Tallberg, P. (2000) Silicon and Its Impacts on Phosphorus in Eutrophic Freshwater Lakes. Academic Dissertation in Limnology, University of Helsinki, Helsinki.

[17] Nurmberg, G.K. (2007) Low-Nitrate-Days (LND), a Potential Indicator of Cyanobacteria Blooms in a Eutrophic Hard Water Reservoir. *Journal of Water Quality Resources*, **48**, 269-283.

[18] Osmon, D. (2008). An Overview of Shallow Lakes Ecology & Management Techniques. *The Lake Connection*. http://www.wisconsinlakes.org/attachments/article/31/08fall_shallowlakesecology&mgmt.pdf

[19] Maulan, S. (2013) Putrajaya Wetland, Malaysia. Department of Landscape Architecture, University of Putra Malaysia, Serdang.