ASSESSMENT ON WATER QUALITY AND TRACE METAL CONCENTRATIONS OF AN URBAN LAKE IN KUCHING RESERVOIR PARK

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ASSESSMENT ON WATER QUALITY AND TRACE METAL CONCENTRATIONS OF AN URBAN LAKE IN KUCHING RESERVOIR PARK

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Declaration

No portion of the work referred to in this dissertation has been submitted in support of an application for another degree of qualification of this or any university or institution of higher learning.

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Table of Contents

Acknowledgement ........................................................................................................ i
Declaration .................................................................................................................. ii
Table of Contents ......................................................................................................... iii
List of Abbreviations ................................................................................................... vii
List of Tables and Figures .......................................................................................... viii
Abstract ...................................................................................................................... x
Abstrak ......................................................................................................................... xi

1.0 INTRODUCTION ................................................................................................. 1
  1.1 Background of Study .......................................................................................... 1
  1.2 Background of Study Area: Kuching Reservoir Park ........................................ 4
  1.3 Problem statements ........................................................................................... 6
  1.4 Research Objectives .......................................................................................... 6
  1.5 Research Questions ........................................................................................... 7

2.0 LITERATURE REVIEW ....................................................................................... 9
  2.1 Urban lakes ......................................................................................................... 9
  2.2 Threats affecting urban lakes ............................................................................ 9
  2.3 Contaminants loads to urban lakes ................................................................... 14
    2.3.1 pH ............................................................................................................. 14
    2.3.2 Temperature .............................................................................................. 15
    2.3.3 Dissolved oxygen ..................................................................................... 16
2.3.4 Total Dissolved Solids and Total Suspended Solids

2.3.5 Turbidity

2.3.6 Nutrients

2.3.7 Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BODs)

2.4 Water Quality Index (WQI) and Interim National Water Quality Standard (INWQS)

2.5 Sustainable management of lakes

2.5.1 Nutrient inactivation by precipitants

2.5.2 Lake flushing/dilution

2.5.3 Sediment removal

2.5.4 Lake management in the context of IWRM

3.0 MATERIALS AND METHODS

3.1 Sampling location

3.2 Sampling time and frequency of sampling

3.3 Sampling techniques and standard method for water quality analysis

3.4 Methodologies for water samples analysis

3.4.1 pH

3.4.2 Temperature

3.4.3 Dissolved Oxygen, Total Dissolved Solids and Salinity

3.4.4 Chemical Oxygen Demand

3.4.5 Ammoniacal Nitrogen (AN)
3.4.6 Biological oxygen demand (BOD$_5$) 32
3.4.7 Total suspended solids (TSS) 32
3.4.8 Nitrate (NO$_3$), Cadmium reduction method 33
3.4.9 Nitrite (NO$_2$-N) 33
3.4.10 Phosphorus (PO$_4^{3-}$) 34
3.4.11 Turbidity 34
3.4.12 Sample preparation and sample digestion for
trace metals analysis 34
3.5 Standard water analysis as stipulated in WQI and INWQSM 35
3.6 Statistical Analysis 35

4.0 RESULTS AND DISCUSSION 37
4.1 pH 39
4.2 Temperature 39
4.3 Dissolved oxygen (DO) 41
4.4 Turbidity 42
4.5 Total Suspended Solids (TSS) 43
4.6 Total Dissolved Solids (TDS) 44
4.7 Chemical Oxygen Demand (COD) and
Biological Oxygen Demand (BOD$_5$) 45
4.8 Nutrient loads 47
4.9 Trace metals 51
4.9.1 Arsenic (As) 51
4.9.2 Zinc (Zn) 52
4.9.3 Lead (Pb) 53
4.9.4 Manganese (Mn) ................................................................. 54
4.9.5 Chromium (Cr) ................................................................. 55
4.10 Statistical analysis of physical-chemical parameters and trace metals concentration among sampling trips .................... 56
4.11 Water Quality Index ........................................................... 59
4.12 Sustainable management of lakes ....................................... 60
  4.12.1 Phosphorus removal by using nutrient inactivation ............. 60
  4.12.2 Aeration using floating fountain .................................... 61
  4.12.3 Lake flushing and retention wall .................................. 61
  4.12.4 Sustainable management of lakes in context of IWRM ....... 62

5.0 CONCLUSIONS ........................................................................... 64
  5.1 Current Water Quality of the lake in Kuching Reservoir Park ...... 64
  5.2 Summary of trace metals presence in the lake water .............. 64
  5.3 Recommendations for the sustainable of lake management ....... 65
  5.4 Limitations of the study ....................................................... 66

REFERENCES ................................................................................. 67

APPENDIX .......................................................................................... 71
## List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AN</td>
<td>Ammonical Nitrogen</td>
</tr>
<tr>
<td>BOD</td>
<td>Biological Oxygen Demand</td>
</tr>
<tr>
<td>COD</td>
<td>Chemical Oxygen Demand</td>
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<tr>
<td>DBKU</td>
<td>Kuching North City Hall <em>(Dewan Bandaraya Kuching Utara)</em></td>
</tr>
<tr>
<td>DO</td>
<td>Dissolved Oxygen</td>
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<td>INWQS</td>
<td>Interim National Water Quality Standard</td>
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<td>IWRM</td>
<td>Integrated Water Resource Management</td>
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<td>NAHRIM</td>
<td>National Hydraulic Research Institute of Malaysia</td>
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<tr>
<td>PE</td>
<td>Polyethylene</td>
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<td>ST</td>
<td>Station</td>
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<tr>
<td>TDS</td>
<td>Total Dissolved Solids</td>
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<tr>
<td>TSS</td>
<td>Total Suspended Solids</td>
</tr>
<tr>
<td>WQA</td>
<td>Water Quality Association</td>
</tr>
<tr>
<td>WQI</td>
<td>Water Quality Index</td>
</tr>
</tbody>
</table>
List of Figures and Tables

<table>
<thead>
<tr>
<th>Figure</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1.1</td>
<td>5</td>
</tr>
<tr>
<td>Location of Kuching Reservoir Park (Source: Google Earth, 2014)…</td>
<td>5</td>
</tr>
<tr>
<td>Figure 2.1</td>
<td>24</td>
</tr>
<tr>
<td>Drivers, Pressure, States, Impacts, Responses (DPSIR) model for lake management (Islam et al., 2012)</td>
<td>24</td>
</tr>
<tr>
<td>Figure 3.1</td>
<td>26</td>
</tr>
<tr>
<td>Location of Kuching Reservoir Park</td>
<td>26</td>
</tr>
<tr>
<td>Figure 3.2a</td>
<td>27</td>
</tr>
<tr>
<td>Station S1</td>
<td>27</td>
</tr>
<tr>
<td>Figure 3.2b</td>
<td>27</td>
</tr>
<tr>
<td>Station S2</td>
<td>27</td>
</tr>
<tr>
<td>Figure 3.2c</td>
<td>27</td>
</tr>
<tr>
<td>Station S3</td>
<td>27</td>
</tr>
<tr>
<td>Figure 3.2d</td>
<td>27</td>
</tr>
<tr>
<td>Station S4</td>
<td>27</td>
</tr>
<tr>
<td>Figure 4.1</td>
<td>39</td>
</tr>
<tr>
<td>pH vs. sampling stations</td>
<td>39</td>
</tr>
<tr>
<td>Figure 4.2</td>
<td>40</td>
</tr>
<tr>
<td>Temperature vs. sampling stations</td>
<td>40</td>
</tr>
<tr>
<td>Figure 4.3</td>
<td>41</td>
</tr>
<tr>
<td>Dissolved oxygen vs. sampling stations</td>
<td>41</td>
</tr>
<tr>
<td>Figure 4.4</td>
<td>43</td>
</tr>
<tr>
<td>Turbidity vs. sampling stations</td>
<td>43</td>
</tr>
<tr>
<td>Figure 4.5</td>
<td>44</td>
</tr>
<tr>
<td>Total suspended solids vs. sampling stations</td>
<td>44</td>
</tr>
<tr>
<td>Figure 4.6</td>
<td>45</td>
</tr>
<tr>
<td>Total dissolved solids vs. sampling stations</td>
<td>45</td>
</tr>
<tr>
<td>Figure 4.7(a)</td>
<td>46</td>
</tr>
<tr>
<td>Chemical oxygen demand vs. sampling stations</td>
<td>46</td>
</tr>
<tr>
<td>Figure 4.7(b)</td>
<td>47</td>
</tr>
<tr>
<td>Biological oxygen demand vs. sampling</td>
<td>47</td>
</tr>
<tr>
<td>Figure 4.8(a)</td>
<td>48</td>
</tr>
<tr>
<td>Nitrate vs. sampling stations</td>
<td>48</td>
</tr>
<tr>
<td>Figure 4.8(b)</td>
<td>48</td>
</tr>
<tr>
<td>Nitrite vs. sampling stations</td>
<td>48</td>
</tr>
<tr>
<td>Figure 4.8(c)</td>
<td>49</td>
</tr>
<tr>
<td>Ammoniacal-Nitrogen (AN) vs. sampling stations</td>
<td>49</td>
</tr>
<tr>
<td>Figure 4.8(d)</td>
<td>49</td>
</tr>
<tr>
<td>Phosphorus (P) vs. sampling stations</td>
<td>49</td>
</tr>
<tr>
<td>Figure 4.9(a)</td>
<td>52</td>
</tr>
<tr>
<td>Zinc (Zn) vs. sampling station</td>
<td>52</td>
</tr>
</tbody>
</table>
Table

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 2.1</td>
<td>Best-fit equations for the estimation of subindex values.</td>
<td>19</td>
</tr>
<tr>
<td>Table 2.2</td>
<td>Classification of each water bodies category.</td>
<td>19</td>
</tr>
<tr>
<td>Table 2.3</td>
<td>Management plan for function context in different surrounding inhabited area of urban ecosystem</td>
<td>21</td>
</tr>
<tr>
<td>Table 3.1</td>
<td>Details of water sampling stations.</td>
<td>28</td>
</tr>
<tr>
<td>Table 4.1</td>
<td>Sampling plan and condition of the sampling events.</td>
<td>38</td>
</tr>
<tr>
<td>Table 4.2</td>
<td>Pearson correlation coefficient (r) between water quality parameters, (N=5)</td>
<td>58</td>
</tr>
<tr>
<td>Table 4.3</td>
<td>Mean WQI and Class of lake in Kuching Reservoir Park.</td>
<td>60</td>
</tr>
</tbody>
</table>
Assessment on Water Quality and Trace Metal Concentrations of an Urban Lake in Kuching Reservoir Park

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ABSTRACT

A study of the water quality and trace metal concentrations of an urban lake in Kuching Reservoir Park (or known as Taman Budaya) was conducted for three months, from October 2014 to December 2014. Four sampling stations were selected to represent the open water body in the lake. A total of 16 water quality parameters and 5 trace metals were measured and compared as stipulated in the Malaysian Department of Environment - Water Quality Index (DOE-WQI). In addition, classification according to the Interim National Water Quality Standard (INWQS) was applied. With respect to INWQS, the mean values of physical and chemical variables were temperature: 29.76±0.29 °C; pH: 7.69±0.22; dissolved oxygen (DO): 5.07±0.39 mg/L; total suspended solids (TSS): 204±167.68 mg/L; total dissolved solids (TDS): 84.78±7.47 mg/L; turbidity: 53.8±12.10 NTU; biological oxygen demand (BOD): 1.13 ±0.20 mg/L; chemical oxygen demand (COD): 21.5±0.20 mg/L; nitrite: 0.09±0.02 mg/L; nitrate: 1.0 ±0.28 mg/L; and ammoniacal-nitrogen (AN): 0.05±0.02 mg/L were within the normal range of Class IIB for recreational purposes with an exception of concentration in the lake. Whereas trace metals concentrations were in decreasing order: zinc>manganese>lead>chromium>arsenic. Results showed that based on Malaysian WQI, the lake water status in Kuching Reservoir Park is classified as Class III with the mean value of 65.30, which is considered as moderate water quality. Recommended best management practices (BMPs) are phosphorus removal by using alum as the chemical precipitant, lake flushing and aeration by the adaptation of floating fountain. Three aspects of lake management involving the public’s participation and awareness, institutional cooperation between DBKU as the main authority and research institutions as well as better enforcement by the legislative were crucially emphasized.

Key words: Urban lake, Kuching Reservoir Park, Water Quality Index, trace metals concentration, best management practices.
Kajian Kualiti Air dan Logam Berat di Tasik Bandar, Taman Budaya Sarawak

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Abstrak

Satu kajian tentang kualiti air dan logam berat bagi satu tasik bandar di Taman Budaya telah dijalankan selama tiga bulan, iaitu dari Oktober 2014 hingga Disember 2014. Empat stesen pensampelan telah dipilih bagi mewakili kawasan air terbuka di tasik tersebut. Sejumlah 16 perimeter kualiti air dan 5 logam berat dipilih dan Indeks Kualiti Air (IKA) diambil dan diklasifikasikan berdasarkan Piawai Interim Kualiti Air Kebangsaan (INWQS). Berpandukan piawai pada INWQS, nilai purata perimeter kualiti air bagi pembolehubah-fizikal dan kimia seperti suhu: 29.8±0.29 °C; pH: 7.69±0.22; oksigen terlarut (DO): 5.07±0.39 mg/L; TSS: 204±167.68 mg/L; TDS: 84.78±12.10 mg/L; NTU: 53.8±41.00; BOD: 1.13±0.20 mg/L; COD: 21.5±0.20 mg/L; nitrit: 0.09 ±0.02 mg/L; nitrat: 1.0 ±0.28 mg/L; ammonia nitrogen: 0.05±0.02 mg/L adalah dalam julat normal dengan kecuali tahap kepekatan fosforus di tasik itu. Manakala tahap logam berat dalam keadaan turutan menurun iaitu: zink > mangan > plumbum > kromium > arsenik. Berlandaskan piawai IKA Malaysia, status air tasik di Taman Budaya Sarawak diklasifikasikan sebagai Kelas III, iaitu dianggap sebagai kualiti air yang memuaskan. Antara langkah pemuliharaan tasik yang dicadangkan ialah penyingkiran fosforus dengan menggunakan alun sebagai agen pemendakan kimia, proses pengepaman tasik serta pengudaraan dengan menggunakan penyesuaian air pancutan. Tiga aspek pengurusan tasik iaitu penglibatan dan kadar kesedaran orang awam mengenai kepentingan tasik bandar, kerjasama institusipengajian tinggi dan badan kerajaan iaitu DBKU sebagai pihak pengurusan dan institusi penyelidikan serta penguatkuasaan undang-undang yang teratur dan terancang amatlah ditekankan.

Kata kunci: Tasik bandar, Taman Budaya Sarawak, kualiti air, pemuliharaan tasik.
CHAPTER ONE

INTRODUCTION

1.1 Background of Study

Water like other element of natural resources such as air and soil is essential parts of the life’s sustenance as well as to maintain ecological progress of the ecosystem. Relentless increases in demand of water in supplying people with necessary needs like drinking water and food as well as the needs for recreation use does affecting the ecosystem of water in the long term. Surface water quality is largely predominated by both natural processes such as weathering and soil erosion as well as anthropogenic inputs like municipal and industrial effluents that are also contributing the deterioration of water quality in the region (Kazi et al., 2009). The anthropogenic activities constitute constant polluting sources whereby urban runoff is a seasonal phenomenon which is largely affected by climate within the basin (Singh et al., 2004).

Lakes are places of reflection, relaxation, and repose, but like all our waters, they are being increasingly stressed (USEPA, 2009). The International Glossary of Hydrology briefly defines a lake as an “inland body of water of considerable size” (UNESCO and Water Meteorology Organization, 1992). One of the most elaborated definition of lakes has been provided by Kuusisto (1985) as “a depression or a group of depressions partly or fully filled by water, all parts of the water body that have the same surface, excluding temporary variability, caused by wind or ice, the ratio between in-flow and volume is small enough to let most of the suspended, inflowing material to form bottom sediments, and the surface area exceeds a given minimum value.”
In Malaysia, about 75 lakes have been created to supply the nation’s demand (Sharip et al., 2008), which serves multipurpose functions. Though relatively small in size, lakes perform significant environmental, social and economic functions, ranging from being a source of drinking water, recharging groundwater, acting as sponges to control flooding, supporting biodiversity and providing livelihoods (NAHRIM, 2010). Water in lakes is an easily available source of water for the needs of many sectors of economy such as agriculture, domestic and industrial. These water bodies, whether man-made or natural, fresh water or brackish play a very vital role in maintaining environmental sustainability particularly in urban environments especially in today’s context when the cities are facing the challenges of unplanned rapid urbanization.

Contamination of aquatic ecosystems by nitrogen, phosphorus as well as heavy metals has been observed in water, sediment and organisms. Nitrogen and phosphorus are also present in surface runoffs (non-point pollution) that is, the drainage from the surface layers or underground runoff close to the surface. The runoff from towns and cities usually contains mostly large concentration of inorganic and organic pollutants. All of these pollutants will lead to the deteriorating of the lake’s water quality and thus, depreciating the aesthetic value of the lake.

With rapid industrialization and consumerist life style, sources of environmental pollution have been increased. The pollution occurs both at the level of industrial production as well as end use of the products and run-off. For instance, heavy metals are regarded as serious pollutants in the aquatic environment because of their environmental persistence and tendency to concentrate in aquatic organisms (Yigit et al., 2006). High concentrations of heavy metals in water, sediments, and organisms may result in serious ecological consequences. Most heavy metals released into the environment and subsequently entered the aquatic phase as a result of direct input, atmospheric deposition and erosion due to rain
(Veena et al., 1997). Therefore, aquatic animals are often exposed to elevated levels of heavy metals (Kalay and Canlı, 2000; Farkas et al., 2000; Farkas et al., 2001).

Likewise, the hazardous trace metals and minerals can arise from natural as well as from anthropogenic sources. Natural sources are such as seepage from rocks into water, volcanic activity and forest fires does led to the indirect sources of pollutions (Verma et al., 2013). In worst case scenario, heavy metals are directly absorbed by organisms whereby all these trace metals will be transferred from lower to higher trophic levels of the food chain. The high accumulation of heavy metals in these components can result in serious ecological changes.

Although water quality in Malaysia is monitored by the Department of Environment (DOE), recreational lakes especially urban lakes water quality is still less emphasized. Therefore, to confirm the types of water bodies for urban lake is at a satisfactory level, a regular monitoring should be carried out by related parties. DOE has set a water quality index (WQI) and Interim National Water Quality Standards (INWQS) as a baseline for water quality, which is applicable for both lakes and rivers. Six water quality parameters are used to determine the level of water quality in WQI namely, biochemical oxygen demand ($\text{BOD}_5$), chemical oxygen demand (COD), total suspended solid (TSS), ammoniacal-nitrogen ($\text{NH}_3$-$\text{N}$), pH and dissolved oxygen (DO). As a result of WQI calculation, studied lake will be classified into Class I to Class V. Class I indicate a good water quality and the quality decline as the class is higher.

Hence, protecting lake ecosystems is a pertinent effort that will benefit the country’s public and economic health in such a way that it will helps to preserve and to restore the natural environment for the aquatic and terrestrial living lives that survives surrounding and nearby the lakes. Scientifically valid information on the condition of lake water at national and state level should be established, at least at the baseline information for future trends.
assessment as well as to provide data for the policymakers in enhancing the water monitoring and assessment programs. Lake protection and preservation can only be achieved by making informed lake management policy decisions at and across all jurisdictional levels.

1.2 Background of Study Area: Kuching Reservoir Park

Kuching Reservoir Park is located at Jalan Budaya which is ten minutes walking distance from Kuching town area (Figure 1.1). It is situated at N 01° 33.098’, E 110° 3.17’ and covering an area of 8 hectares (ha). The park itself was built during the British colonial in 1912, primarily built for recreational purpose for the British officers that lived nearby to the park (Benyamin, 2014). Located at the center of the park, the lake is divided into two sections where the upper lake total area is 0.34 hectares and it is linked to the rainwater tank located at the upper hill of the park. Whereas the lower lake, approximately 0.80 ha of area flows to the drainage system that runs to the city. Due to its nature of lentic water, the water basically flows in a slow motion, with the water from the lower lake flows slowly into the drainage system that flows to the city area.
Previously, Kuching Reservoir Park (KRP) used to be the fresh water reservoir for Kuching town. Currently, the public park is frequently visited by the locals as one of the recreational spot as well as fishing spot as it is well stocked with tilapia and sultan fish (Source: Pers. Com., 2014).

Kuching Reservoir Park acts as the “green lung” of the North Kuching, as it is the oldest and among the most visited recreational park in Kuching (Benyamin, 2014). This park is under the authority of Kuching North City Hall (DBKU) and it is managed with the vision that not only meets the requirements of local population around the city of Kuching for recreational use but also as a source of knowledge and education for the community. It is a form of an educational way that the municipal council have actually tagged some of the trees’ with their scientific names on the tree trunks as an information for the visitors.
1.3 Problem statements

Lakes are often regarded as an undervalued resource. Pollution and habitat degradation as a result of run-offs from the city due to anthropogenic activities and lack of proper sewage as well as the erosion of loose surface soils nearby lakes resulting in the increase of total suspended solids (TSS) and sediment content which cause water quality deterioration in lakes. Lack of management in monitoring the water quality by the responsible authority, especially urban lakes for recreational purposes has led to the loss of function value in many lakes.

In the case of lake in Kuching Reservoir Park, the potential factors that are affecting the water quality of the lake are such as fertilizer run-offs from the shrubs and trees. Due to the location of Kuching Reservoir Park that is right in the middle of Kuching city which exposed the lake to the city run-off. In static waters like lakes, it is very often associated with that the decaying of biomass that also causes eutrophication and the growth of algae-bloom which later affecting the lives of the aquatic organisms in the lakes.

Based on the previous explanation, the preferred research problem is developed and it is associated with impact of urbanization to the lake in relation of current status of the water quality of the lake itself. Selected parameters for the water quality assessment are proposed in such a way that it will determines the source of pollutants that are affecting the lake water condition. With all of the data obtained, it is the aim of this research to provide if not the best, perhaps the recommended measures that should be taken by DBKU in managing the lake in order to continue the sustainability of the aquatic organisms as well as the aesthetic value of the lake in the park. For these reasons, the following research objectives are developed.
1.4 Research Objectives

This study is aimed to analyze and evaluate the current water quality status and trace element concentrations of selected elements of the lake based on INWQS (Interim National Water Quality Standard) of Malaysia and Water Quality Index (WQI) as well as to provide if not the best, perhaps the appropriate best management practices (BMPs) for the sustainable of lake management.

1.5 Research Questions

In order to meet the objective and to response the overall problem statement, the following research questions were developed:

Research Question 1: What is the current water quality status and trace metal concentrations of the lake?

This research question is determined to investigate the current water quality status of the lakes, since there is absence of reports in regards of assessment and monitoring processes were recorded thus far. In addition to that, the research questions are seeks to know on the presence of any trace metals in which five elements were selected along with other physical-chemical parameters. With respect to that, WQI and INWQS classifications were used as standardization.

Research Question 2: What are the factors that affecting the water quality of the lake?

In order to answer this research question, factors or potential sources which may influence the water quality status of the lake are identified. Thus, data pertaining on how the potential drivers that are affecting the water quality will be recorded analysed and evaluated. Here, statistical analyses are also applied in order to interpret the relationship among the water parameter concentrations.
Research Question 3: What is recommended remedial measures adapted by DBKU in managing the lake?

This research question is to identify the recommended best management practices (BMPs) which are expected in the future and the possible future that might benefit the sustainable of lake management. In answering this question, a few approaches were suggested based on the current status of the lake.
2.1 Urban lakes

Lakes are an essential part of the global water resource but unfortunately often been looked at in a purely lake context (UNEP, 2007) due to the fact that urban lakes have been a victim to unplanned urbanization in many cities. This includes pollution like effluent from industries (Sabri et al., 2014) as well as anthropogenic activities (Mishra et al., 2011), eutrophication, ungoverned tourist activities (Yang et al., 2010) and cultural misuse (Shirude et al., 2014).

Lakes are generally sensitive to pollutants and with high water storage capacity and long retention times, chemical and organic pollutants can appear in rather high concentrations and accumulate in bottom sediments. A lake and its drainage basin are fundamentally linked, and interactions between humans, water and land resources are critical factors influencing a lake’s health and its potential long-term uses (UNEP, 2007).

2.2 Threats affecting urban lakes

Lakes and ponds are significantly contributed in the increase of the urban life’s centres, especially in providing the recreational and educational activities as well as to mitigate the urban climate (Naselli-Flores, 2008). One of the major problems that threatened lakes includes eutrophication, sedimentation and weed infestation (Sharip & Zakaria, 2008). About 60% of 90 lakes which were studied for desk top study done by National Hydraulic Research Institute of Malaysia (NAHRIM) have experienced higher level of eutrophication state.

Nonpoint source (NPS) pollution is defined as any source of water pollution which
does not meet the legal definition of “point source”, as defined in section 502(14) of Clean Water Act. Differs from “point source” pollution, NPS comes from many diffuse sources such as from the land runoff, precipitation, atmospheric deposition, drainage system as well as due to hydrologic modification (USEPA, 2014). Non-point pollutions are an example of source that are giving threats to urban lakes in which the pollutants are discharged via the drainage as well as from the surface layers or underground runoff. Inevitably, large urban developments are subjected to urban run-off especially during periods of heavy rain. It is a common scenario that rainwater is collected in drains and it will then flows to the sewage collection and treatment facilities before being discharged to river or lake. While in other cities, rainwater is channeled directly to the closest water body. All of these aspects will lead to the deteriorating of the lake’s water quality and thus, depreciating the aesthetic value of the lake. Report states that nonpoint source pollution is the leading remaining cause of water quality problems, especially to the urban lakes (EPA, 2003). The effects of nonpoint source pollutants on specific waters vary and may not always be fully assessed. However, we know that these pollutants have harmful effects on drinking water supplies, recreation, fisheries and wildlife. Particularly, among the water quality problems associated with the urban-off are the high levels of oil and lead which are sourced from automobiles (WQA, 1996) as well as a variety of trace metals and pollutants from the nearby local industry activities.

For instances, a study on water quality assessment at Lake Ontario found that the northern and southern site of the lake gave a difference and opposite results. In this case, an altered hydrology and runoff from the urban watershed and a nearby major highway have resulted in poor water quality and warmer waters at the northern site of the lake. In contrast, the southern site has considerably cleaner and cooler water, as it is influenced by exchange of good-quality water with Lake Ontario due to the fact that the lake is an important spawning and nursery habitats for fishes (Seilheimer et al., 2007). Basically, the degradation of water
quality has reduced the historically large stand of emergent vegetation to fringe emergent beds to the north and south of the Bay. Hence, the results obtained show that inputs from the heavily urbanized watershed have led to differences in degraded water quality at sites close to the creek mouths compared to sites farther from the creeks, which is yet affected by the urbanization and further away from the wash-off the city.

On the other hand, comprehensive study was done by Yang (2010) whereby a ten-year analysis (2000-2009) data were monitored every other months in each year as well as evaluation of the variations on water quality parameters were conducted to investigate the delineation of the water quality of Baiyangdian Lake, North China. The results showed that the variation of pollution indexes for total phosphorus (TP), total nitrogen (TN) and ammoniacal-nitrogen (AN) took a larger fluctuation and the two “pollution peaks” appeared in the year of 2000 and 2006 in the comprehensive pollution index curve. The pollution peaks detected as what appeared to be an occurrence of “died fish event” as the result of declination of the water level and due to the deterioration of water quality. Some of the factors that contribute to this occurrence were the domestic wastewater inputs, the influent of upstream rivers of through runoff in flood seasons, the release of endogenesis sediment and the pollutants of tourism activities.

Whereas on the local state, a research was done by Shuhaimi-Othman, Lim and Mushrifah (2007 & 2008) to investigate the changes of water quality Tasik Chini, Peninsular Malaysia within the duration of 12 months in association to seasonal variation and other activities that were occurring around the lake vicinity. The physical and chemical variables were tested and based on the results, the water in Tasik Chini is classified as class II on Malaysian WQI that is suitable for recreational activities and does allow body contact. With respect to the Interim National Water Quality Standard (INWQS), temperature was within the normal range, conductivity, TSS, nitrate, sulphate and TDS are categorized under class I.