EVALUATION OF VARIOUS WATER QUALITY INDICES FOR INDEXING RIVER WATER

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EVALUATION OF VARIOUS WATER QUALITY INDICES FOR INDEXING RIVER WATER

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DECLARATION

I declare that this dissertation is based on my original work, except for quotations and summaries, each of which has been fully acknowledged.

_________________________  ____________________________
DATE                      CHOO CHEE YUAN
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Evaluation of Various Water Quality Indices for Indexing River Water

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ABSTRACT

Water resources are of critical importance to both natural ecosystem and human development. The quality of water in any ecosystem provides significant information about the available resources for supporting life in that ecosystem. A good water quality is important for a healthy river and ecosystem. In order to determine the status of the river water, various water quality parameters are measured to determine whether it is safe for any purpose. The water quality parameters can be divided into physical, chemical and biological. Most of the physiochemical and microbiological parameters were measured and classified based on the National Water Quality Standard (NWQS) and Water Quality Index (WQI) to evaluate the status of river water quality. In this study, three water quality monitoring approaches was used to evaluate the Waterfront and Satok Bridge river water which are Water Quality Index (WQI), average National Water Quality Standards (NWQS) and Partial Least Square Water Quality Index (PLS-WQI). PLS-WQI is designated based on Partial Least Square Regression that can consider expand or restrict parameters simultaneously instead of the conventional univariate manner according to NWQS. Besides, PLS-WQI is a set of computationally generated training sets that can be used to predict the water quality of unknown samples. In this study, the river water quality was categorized as Class II-Class III under WQI which is moderate to good water quality with index ranged from 75 to 86. The PLS-WQI was more sensitive than average NWQS because it took into account the entire value for each parameter and not only interpreted the class which each parameter value fell on it. PLS-WQI is a method that can consider multiple parameters simultaneously. Therefore, when the turbidity parameter was added, it showed that PLS-WQI with 7 parameters was more sensitive than the PLS-WQI with 6 parameters because PLS-WQI took the absolute value of the parameter into account to determine the classes of the water quality. Therefore, PLS-WQI should be encourage to be used in the evaluation of river water quality status in Malaysia to meet with the specific problems.

Keywords: Water quality index, national water quality standards, partial least square regression, river water quality
Penilaian Pelbagai Penentu Indeks Kualiti Air untuk Pengindeksan Air Sungai

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ABSTRAK

Sumber air adalah penting untuk ekosistem semula jadi dan pembangunan manusia. Dalam mana-mana ekosistem, kualiti air telah menyediakan maklumat yang penting untuk mendukung kehidupan dalam ekosistem itu. Kualiti air yang baik adalah penting untuk sungai dan ekosistem. Pelbagai parameter kualiti air telah diuji untuk menentukan status air sungai supaya air sungai adalah selamat digunakan. Parameter kualiti air boleh dibahagikan kepada fizikal, kimia dan biologi. Kebanyakan parameter telah diuji dan dikelaskan berdasarkan Indeks Kualiti Air (WQI) dan NWQS untuk penilaian status kualiti air sungai. Dalam kajian ini, tiga pendekatan pengawasan kualiti air telah digunakan untuk menilai air sungai Waterfront dan Jambatan Satok ialah Indeks Kualiti Air (WQI), piawaian kualiti air kebangsaan (NWQS) dan Partial Least Square Indeks Kualiti Air (PLS-WQI). PLS-WQI direka berdasarkan Partial Least Square Regression yang boleh menambahkan atau mengurangkan parameter berdasarkan kepada garis panduan daripada NWQS. Selain itu, PLS-WQI adalah satu set pengiraan yang dihasilkan untuk menentukan kualiti air sampel yang tidak diketahui. Dalam kajian ini, kualiti air sungai telah dikategorikan sebagai Kelas II Kelas III di bawah WQI antara 75 hingga 86 di mana kualiti air sungai adalah dalam lingkungan sederhana dan baik. PLS-WQI adalah lebih sensitif daripada purata NWQS kerana ia mengambil kira nilai sebenar bagi setiap parameter dan bukan sahaja mengambil nilai di mana kelas yang jatuh ke dalamnya untuk menentukan kualiti air sungai. PLS-WQI adalah satu kaedah yang boleh mempertimbangkan pelbagai parameter serentak. Oleh itu, apabila parameter kekeruhan diambil kira, ia menunjukkan bahawa PLS-WQI dengan 7 parameter adalah lebih sensitif daripada PLS-WQI dengan 6 parameter kerana PLS-WQI mengambil nilai mutlak untuk menentukan kelas-kelas kualiti air. Oleh itu, PLS-WQI perlu menggalakkan untuk digunakan dalam penilaian status kualiti air sungai di Malaysia untuk menyelesaikan masalah tertentu.

Kata Kunci: Indeks kualiti air, piawaian kualiti air kebangsaan, Partial Least Square regression, kualiti air sungai
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<td>DOE</td>
<td>Department of Environment</td>
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<td>EC</td>
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1.1 Research Background

Water is the most important natural resource that supports the basic human need. It is a valuable national asset (Akkaraboylna and Raju, 2012). Besides, water resources play a vital role in various sectors of economy such as agricultural, livestock production, fisheries and other creative activities apart from the need for drinking. Therefore, clean and adequate water supply is a necessity for the health of all living organisms and ecosystems, including people and their activities (Mophin and Murugesan, 2011).

Water sources are mainly in the form of rivers, lakes, glaciers, rain water and ground water. In Malaysia, about 95% of water comes from the inland river systems; they play a significant role in providing water resources for many human purposes including industrial and domestic uses, recreational, transportation as a means of waste disposal (Mohamed, 2008). The quality of river water is directly affected by the amount of waste discharged into the river and its assimilative capacity (Mohamed, 2008). The quality and quantity of available water resources play an
important role for the development of a nation (Akkaraboylna and Raju, 2012). Water demand has increased steeply and greater pressure is on preserving the current water resources as well as finding alternative courses of action to improve the water quality as the country progresses towards Vision 2020 (Faridah et al., 2012). Regular water quality monitoring is one of the priorities of environmental monitoring effort to minimize the incidence of pollutant-oriented problems, and to provide water of appropriate quality for various (Mophin and Murugesan, 2011).

Water quality monitoring data can be used to track response to management regimes aimed at improving water quality (Cleophas et al., 2013). Constant review of the monitoring requirements, detection of point source and non-point source pollutants as well as proper revision of water quality standards are necessary for sustainable management of water resources (Mamum and Zainudin, 2013). By regular monitoring of the physical and chemical properties of water quality, it is possible to detect changes and implement response measures to mitigate detrimental change before a situation worsens (Cleophas et al., 2013).

Water quality is a phrase to describe the chemical, physical and biological characteristics of water. Determination of status of water quality for a river or any other water sources is highly indeterminate. Therefore, it is necessary to have a competent model to predict the status of water quality and to advice for type of water treatment for meeting different demands (Bai et al. 2009). However, one of the difficult tasks facing by environmental managers is how to transfer their interpretation of complex environmental data into information that is understandable and useful.
to technical and policy individuals as well as the general public. Therefore, the most effective ways to communicate information on environmental trends and river water quality in particular is with indices (Bai et al., 2009). Water quality indices are computed for classification of water. In Malaysia, the classification of rivers by the Department of Environment (DOE) is based on water quality index (WQI). Water Quality Index (WQI) is a compilation of a number of parameters which consists of six determinants: dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), ammoniacal nitrogen (NH$_3$-N), suspended solids (TSS) and pH that can be used to determine the overall water quality. The index is a means to summarize a number of water quality measurements into a numerical form to indicate the status of water quality (Akkaraboylna and Raju, 2012).

WQI is an important tool for management and decision making purposes (Tyagi et al., 2013). However, there are some limitations where the index may not carry enough information on the water quality on the water quality and not all parameters are taken into account (Ansari and Hemke, 2013). Therefore, the National Water Quality Standards (NWQS) was used to serve as a benchmark to provide recommended water quality criteria according to parameters for Malaysia.

Various water quality indices have been developed to integrate water quality variables worldwide to provide a whole and interpreted picture of water quality. A water quality index has been designed computationally generate a training set based on the guideline of National
Water Quality Standards (NWQS) and used it to predict the water quality of unknown samples which called Partial Least Square Water Quality Standards (PLS-WQI). It is an extension of National Water Quality Standards where Partial Least Square is incorporated for prediction of water quality (Sim et al., 2015). Partial least squares is a method used for constructing predictive models when the factors are many and high collinear (Tobias, 2014). This index will be calculated using the algorithm written in-house in Matlab.

1.2 Problem Statement

Water quality is a problem receiving increasing attention. The Department of Environment (DOE) of Malaysia used WQI to evaluate the status of river water quality by using WQI range even it is not an absolute measure of degree pollution or the actual water quality (Bai et al., 2009). The influence of these parameters on the surface water quality and subsequently in calculating WQI is questionable because some important parameters are not considered in the WQI (Zali et al., 2011) which are faecal coliform count, total coliform count, nitrate, phosphorus and etc.

Besides, WQI calculation takes time and effort which occasionally associated with unintentional errors during sub-index calculations (Gazzaz et al., 2012). Water quality index contain less information than the raw data that they summarize. Many uses of water quality data cannot be met with indexes which are less suited to specific questions. NWQS which contribute more details and information for the classification of water quality into five classes based on the
various water quality parameters. Besides, there is no mathematical calculation to derive an index to indicate the overall water quality. On the other hands, PLS-WQI can be employed to consider multiple parameters simultaneously instead of the conventional univariate manner. Sofwan (2013) evaluated NWQS and PLS-WQI revealed that the two indices correspond well with the WQI in determining the river water quality status.

1.3 Objectives

Partial Least Squares Water Quality Index (PLS-WQI) can be employed on water quality data with more than six parameters nonetheless how would additional parameters affect the index is unknown.

The objectives of the study are:

1. to evaluate the water quality of Sarawak River based on different water quality indices.
2. to evaluate the sensitivity of PLS-WQI when parameter added.
CHAPTER 2

LITERATURE REVIEW

2.1 Water and Water Pollution

Rivers play an important role in providing water resources for human and ecosystem survival and health. Besides, rivers comprise the most important water resources for irrigation, domestic water supply, industrial and other purposes in a watershed, thereby tend to stimulate serious hygienic and ecological problems (Fawaz et al., 2013). Nevertheless, most of the urban rivers are deteriorated due to high anthropogenic activities, urbanization practices, irrigational and livestock activities along the river bank (Mophin and Murugesan, 2011).

Pollution is the introduction of a contamination into the environment (Owa, 2015). The sources of water pollution categorized into two classes which are direct and indirect contaminant sources. The direct sources of water pollution include effluent outfalls from factories, refineries, waste treatment plants that discharge varying quality of fluids directly into urban water supplies. On the other hand, the indirect sources of water pollution include the contaminants that enter the water supply from soils or groundwater system which consists of the residue of human
agricultural practices and improperly disposed of industrial wastes. Besides, indirect sources also can caused by the contaminants from the atmosphere via rain water that derived from human practices such as gaseous emissions from automobiles and factories.

Water pollution has negative effects on the living and also the environment on human and aquatic communities are many and varied. Water pollution causes approximately 14,000 deaths per day which mostly due to contamination of drinking water by untreated sewage in developing countries (Owa, 2015). It leads to damage to human health. The drinking water is affected and causes the health hazards. Besides, the ecological balance of a body of water is altered.

The range of deterioration in water quality varied depending on the percentage of change in land use. Therefore, prevention and controlling river pollution with reliable evaluation of water quality are imperative stipulation for effective management (Fawaz et al., 2013). Malaysia has made significant efforts to improve the river water quality in recent years after realizing the seriousness of the threat potentially posed to river water (Faridah et al., 2012).

2.2 Water Quality

Water resources are of critical importance to both natural ecosystem and human development. The quality of water in any ecosystem provides significant information about the available resources for supporting life in that ecosystem. Good quality of water resources depends on a
large number of physicochemical parameters and biological characteristics. Most of the physicochemical and microbiological parameters were measured and classified based on National Water Quality Standard (NWQS) and Water Quality Index (WQI) to identify the effects of anthropogenic activities on water quality. The Department of Environment (DOE) employs Water Quality Index (WQI) to evaluate the status of the river water quality serving as the basis for environment assessment of a watercourse.

2.3 Water Quality Parameters

Good water quality is important for a healthy river and ecosystem. Various water quality parameters are measured in order to determine the status of the river water whether it is safe for any purpose. The water quality parameters can be divided into physical, chemical and biological.

2.3.1 Physical Parameters

2.3.1.1 Turbidity

Turbidity indicates the amount of fine particles suspended in water. It is caused by suspended and colloidal matter such as clay, silt, and finely divided organic and inorganic matter, plankton and other microscopic organisms (APHA, 1998). High concentration of particles can damage
the habitat for fish and other aquatic organisms (Said et al., 2004). Excessive turbidity is generally related to possible microbiological contamination (Fawaz et al., 2013).

2.3.1.2 Temperature

Water temperature as a function of depth is used to identify the source of water supply (APHA, 1998). Water temperature has direct and indirect effects on nearly all aspects of stream ecology. Water temperature has a direct link with toxic absorption, salinity and dissolved oxygen. Temperature also influences the rate of photosynthesis by algae and aquatic plants. The increase in temperature would reduce the dissolve oxygen bringing harmful effects to the aquatic life. Human activities affecting water temperature include the discharge of industrial effluents, agriculture and forest harvesting.

2.3.1.3 Total Suspended Solids (TSS)

Total suspended solids (TSS) are usually referred to particles in water larger than 0.45µm. These particles are transported by flowing water and settle out when the flow is insufficient to keep them in suspension. Water high in suspended solids may be esthetically unsatisfactory for daily use including bathing. High suspended solids also prevent sunlight from penetrating water and the plants in aquatic cannot do photosynthesis (APHA, 1998).
2.3.2 Chemical Parameters

2.3.2.1 Hydrogen-ion Concentration (pH)

pH is one of the most important and frequently used to examine water quality as the practice of every phase of water supply and wastewater treatment is pH-dependent (APHA, 1998). pH measurement reveals whether a solution is acidic or alkaline whereas if the solution has an equal amount of acidic and alkaline molecules, the pH is considered neutral. The pH scale is logarithmic and runs from 0.0 to 14.0 with 7.0 being neutral (Ahmed et al., 2013). The readings with less than 7.0 indicate acidic solutions while, readings higher than 7.0 indicate alkaline or base solutions.

Natural waters usually have pH values in the range of 4 to 9, and most are slightly basic because of the presence of bicarbonates and carbonates of the alkali and alkaline earth metals (APHA, 1998). The nutrient runoff from fertilizer could lead to increased algae growth and higher pH. On the other hand, low pH which is pH less than 4 can be harmful to aquatic organisms affecting the physiological functions of aquatic life through the reduction of enzyme activity and effectiveness (Kitt, 2000).
2.3.2.2 Electrical Conductivity (EC)

Conductivity is a measure of the ability of an aqueous solution to carry an electric current (APHA, 1998). It is often used as an indirect measure of salinity and total dissolved solids (TDS). Inorganic compounds are good conductors compared to organic compounds due to the input of industrial effluents making conductivity a good indicator of inorganic pollution. Therefore, measuring conductivity will provide a good indication of the state of inland water with respect to the suitability of water for both aquatic life and drinking (Carr and Rickwood, 2008).

2.3.2.3 Salinity

Salinity is an important property of industrial and natural waters which was originally perceived as a measure of the mass of dissolved salts in a given mass of solution (APHA, 1998). High levels of salt affect plant growth, water quality and soil quality. The ionic composition of inland water sources is dependent on the surrounding environment.

2.3.2.4 Dissolved Oxygen (DO)

Dissolved oxygen is a measure of the amount of oxygen freely available in water which is temperature dependent (Said et al., 2004). The oxygen is the single most important gas for most