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CHUA LI YING

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I hereby declare that this dissertation contains my original research work except for the sources of findings reviewed herein, which have been duly acknowledged.

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CHUA LI YING

HS2005-2413

VERIFIED BY

Signatures

1. **SUPERVISOR**

(PROF. DR. MOHD. HARUN ABDULLAH)

2. **EXAMINER 1**

(DR. KAWI BIDIN)

3. **EXAMINER 2**

(DR. VUN LEONG WAN)

4. **DEAN OF SCHOOL OF SCIENCE AND TECHNOLOGY**

(SUPT/KS, PROF. MADYA DR. SHARIFF A. K. OMANG, ADK)

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ABSTRACT

The purpose of this study is to determine the water quality of Sungai Tuaran, Sabah and its tributaries based on the parameters pH, temperature, electrical conductivity (EC), suspended solids (SS), total dissolved solids (TDS), concentration of nitrate (NO_3^-), and concentration of sulphate (SO_4^{2-}) via both *in-situ* and laboratory analyses. The results obtained are compared with Interim National Water Quality Standards (INWQS) and Malaysia Drinking Water Standards where relevant. The average pH value is 7.65 ± 3.91, while the EC averages 60.10 ± 2.83 μS cm^{-1}. Mean of TDS fall between the range of 0.00 mg L^{-1} to 166.7 ± 30.6 mg L^{-1} and mean of SS is from 26.7 ± 11.5 mg L^{-1} to 1666.7 ± 41.6 mg L^{-1}. Nitrate concentration averages between 1.47 ± 0.06 mg L^{-1} and 4.00 ± 0.20 mg L^{-1}. The mean concentration for sulphate is from 2.0 ± 0.0 mg L^{-1} to 14.0 ± 0.0 mg L^{-1}. Based on INWQS, the overall water quality is acceptable; however the SS values indicated pollution in certain parts of the river. For drinking water quality, the concentration of TDS, NO_3^-, and SO_4^{2-} are all below the Malaysia Drinking Water Standards benchmark levels. Related parameters are also statistically correlated to determine the significance of one variable towards another. Correlation of EC-TDS, EC–NO_3^- concentration, and EC–SO_4^{2-} concentration show positive and strong significance. Through observation and inferring to the obtained results, anthropogenic activities do play a major role in affecting river water quality.

ABSTRAK

Kajian ini dijalankan untuk menentukan kualiti Sungai Tuaran, Sabah serta cawangan-cawangannya berdasarkan kepada parameter-parameter pH, suhu, kekonduksian elektrik, jumlah pepejal terampai, jumlah pepejal terlarut, kepekatan kandungan nitrat (NO_3^-), dan kepekatan kandungan sulfat.(SO_4^{2-}) melalui kaedah *in-situ* serta analisis makmal. Keputusan yang diperoleh telah dibandingkan dengan Piawai Kualiti Air Kebangsaan Interim dan Piawai Air Minuman Malaysia di mana ada kaitan. Nilai purata pH ialah 7.65 ± 3.91, manakala purata kekonduksian elektrik ialah 60.10 ± 2.83 µS cm^{-1}. Nilai min jumlah pepejal terlarut berada dalam julat 0.00 mg L^{-1} to 166.7 ± 30.6 mg L^{-1} dan julat min jumlah pepejal terampai ialah dari 26.7 ± 11.5 mg L^{-1} hingga 1666.7 ± 41.6 mg L^{-1}. Kepekatan nitrat berpurata antara 1.47 ± 0.06 mg L^{-1} dan 4.00 ± 0.20 mg L^{-1}. Min kepekatan sulfat berada dalam julat 2.0 ± 0.0 mg L^{-1} hingga 14.0 ± 0.0 mg L^{-1}. Secara keseluruhan, kualiti air adalah memuaskan berdasarkan , tetapi nilai jumlah pepejal terampai telah menunjukkan bahawa adanya pencemaran di sebilangan kawasan sungai. Bagi kualiti air minuman, kepekatan jumlah pepejal terlarut, NO_3^-, dan SO_4^{2-} kurang daripada tahap minimum piawai. Parameter yang berkaitan juga telah dijalankan korelasi statistik untuk menentukan signifikan suatu pembolehubah terhadap suatu pembolehubah yang lain. Korelasi kekonduksian elektrik-jumlah pepejal terlarut, kekonduksian elektrik-kepekatan NO_3^- , dan kekonduksian elektrik-kepekatan SO_4^{2-} menunjukkan hubungan yang positif. Melalui pemerhatian dan hubungkaitan keputusan yang diperolehi, aktiviti-aktiviti manusia sememangnya memainkan peranan penting dalam mendatangkan kesan kepada kualiti air sungai.

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LIST OF SYMBOLS

km	kilometer
mm	milimeter
km^2	kilometer square
m^3	meter cube
MLd^{-1}	mega liter per day
$mg\ l^{-1}$	miligram per liter
µm	micrometer
°C	degree Celsius
μScm^{-1}	micro Siemens per centimeter
ml	mililiter
µl	microliter
<	less than
>	greater than
g	gram
n	number of samples
r	correlation coefficient
r^2	regression value
INWQS	Interim National Water Quality Standards

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CHAPTER 1

INTRODUCTION

1.1 GENERAL INTRODUCTION

Rivers come in a myriad shapes and sizes but there is one thing in common, they all start from one high point known as the headwater and flow down to lower points. As the water flows down, small streams meet and merge forming larger rivers, and at the same time gather more water from springs, rain, or snow melt. Eventually these rivers will either empty out into an inland body of water, like a lake, and is known as a closed watershed; or, in open watersheds, flow out into the oceans (Jackson et al., 2001).

Rivers make up only 0.2 percent of all the fresh water on Earth, but apart from being a water supply source, rivers also play a variety of important roles in the environment. Land mass is both carved and created by rivers by erosion and depositing of sediments. With time, the flow of rivers can change the landscape of an area (Natureworks, 2003). Rivers are also important in transporting water, organisms and nutrients from one area to another; creating habitats and help drain rainwater (Kingsolver, 2000).

In Malaysia, river water quality monitoring programmes have been carried out since 1978 to obtain baseline data and provide information for pollution sources identifications. Based on six major parameters: Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammoniacal Nitrogen (NH_3-N), Suspended Solids (SS), and pH, the Water Quality Index (WQI) is calculated and rivers are classified in accordance to the National Water Quality Standards for Malaysia (NWQS). In 2005, 26 rivers have been placed under the Pollution Prevention and River Water Quality Improvement Programme carried out by the Department of Environment (DOE Environmental Quality Report, 2005).

Generally, rivers in Malaysia are mainly polluted by excessively high sewage load and discharges from agricultural activities, latex based industries, and crude palm oil factories. High SS pollution is from earthworks activities such as land clearing and sand dredging. However, Malaysia still depends on its rivers for water supply, both drinking and daily usage, and thus the quality of the rivers' water are of utmost importance. For instance, it should be maintained to be in compliance to safe drinking water levels (DOE Annual Report, 2006).

In addition to anthropogenic pollution of rivers, salt water intrusion into the fresh water systems will cause the decline of river water quality. Intrusions may happen due to tidal changes (Uncles et. al, 1995) and possibly increase of sea-levels (Glick, 2004). The latter is an internationally debated issue as it is part of the global warming and climate change phenomenon. Its effects are still unconfirmed as it is a complex study which requires thousands of years of data and a lot of modelling and estimations (van der Veen, 2001).

1.2 OBJECTIVES OF STUDY

In view of the recent issues of global warming and climate change, the aim of this study is to initiate an inventory of data regarding river water quality. Sungai Tuaran is highly utilised for multiple domestic, commercial, agricultural and industrial uses, hence the determination of its quality is important. This research is also to obtain relevant data of water quality parameters to be used for further studies of the same area or other similar studies.

The objectives of this study are:

1. To obtain *in-situ* parameters – pH, temperature, and electrical conductivity (EC).
2. To measure the nitrate and sulfate content of the river.
3. To measure the suspended solids (SS) and total dissolved solids (TDS) of the river.

CHAPTER 2

LITERATURE REVIEW

2.1 RIVER WATER QUALITY

Novotny and Chesters (1981) defined that water quality indicates the composition of water as affected by natural processes and by human activities, expressed in terms of measurable quantities and related to intended water use.

Deterioration of river water quality may be caused by point and non-point source pollution, especially from anthropogenic activities (Carpenter *et al.,* 1998). Point source pollution, from both domestic and industrial effluents, can be easily localised. However, non-point pollution, such as runoff after a period of rain, is less obvious (Fytianos *et al.,* 2002). River water quality may also vary depending to the sampling location (upstream or lower reaches of the river), the geological morphology, as well as the vegetation and activities along the river (Brezonic *et al.,* 1999).

River water quality degradation is strongly linked to anthropogenic activities (Sarkar *et al.,* 2006) and also due to environmental occurrences borne from global warming, such as climate change (Izrael *et al.,* 1990). Incidentally, most of the increase in global temperature since the mid-20th century is highly contributed by human activities, for instance, the observed increase in anthropogenic greenhouse gas concentrations (IPCC, 2007).

2.2 GLOBAL WARMING AND CLIMATE CHANGE

Global warming is one of the most widely discussed phenomena to occur in this century. Due to increases in greenhouse gas emissions, changes in climate temperature may influence ecosystems, geographical processes, and also human activities (Kont *et al.*, 2003). Ice is melting, rivers are running dry, and coasts are eroding. Although some may argue that throughout the centuries, climate has been notoriously fickle; statistics show that global temperatures are shooting up faster than any other time in the past thousand years. Experts believe that the rapid warming is not caused by natural forces such as volcanic eruptions, but more likely due to human activities. Forest clearing, and burning of oil, coal, and gas have increased carbon dioxide and other heat-trapping emissions into the atmosphere, faster than the ability of plants and oceans to soak them up.

2.2.1 Climate Change and Water Quality

The increase of overall global temperature raises the temperature of water bodies. Increasing water temperatures change hydrodynamics, expand the thermal stratification period, and deepen the thermocline. These shifts then increase nutrient release from sediments and lead to a change in nutrient circulation. Water temperature is a key parameter in most biological systems as it directly influences water chemistry, biochemical reactions and growth/death of biota. Higher water temperatures will cause changes in fish habitats as well as the composition of phytoplankton and zooplankton species depending on tolerance levels. However, it is not clear whether these changes will have overall positive or negative effect on aquatic ecological systems (Komatsu *et al.*, 2007).

Rivers are the primary transport mechanism for suspended sediment, pollution and nutrients to enter the catchment areas. The significance of a given river with respect to sediment, nutrient or pollution loading depends upon both the discharge of the river and the concentrations of the various materials contained in the river water. In areas where river flows decrease, pollution concentrations will rise because there will be less water to dilute the pollutants.

In a warmer climate, the earth can be expected to experience more variable weather with a likelihood of more floods, drought, and more intense hurricanes or typhoons. These phenomena bring about effects to the hydrological systems (Izrael *et al.*, 1990). Increased frequency of severe rainstorms could increase the amount of chemicals that run off from farms, lawns, and streets into the rivers, lakes, and bays. The tendency for rainfall to be more concentrated in large storms as temperatures rise would tend to increase river flooding, without increasing the amount of water available (EPA, 2006).

As global warming could cause changes in the timing and amount of precipitation in various countries, water quality may be affected greatly. In regions of low precipitation, salt concentrations in water may increase greatly. High salt concentration in water and a reduction of water supply may impair drinking water quality and food production. Conversely, increased rainfall will cause frequent flooding and spread water-borne diseases which directly or indirectly threaten the health of people in developing countries. Permafrost degradation may cause leaching from disposed wastes, resulting in contamination of the groundwater. If global warming worsens the water quality or increases inundation, epidemics such as diarrhoea, cholera and dysentery could spread (Izrael *et al.*, 1990).

2.2.2 Glacier Melts and Water Quality

The evidence of warming is significant. According to Glick (2004), since 1912, the snows of Kilimanjaro have melted more than 80%. The Artic sea ice has decreased by 9% in a decade and an estimated 15% of thinning has occurred in the past 30 years. Ice shelves in Greenland and Antarctica have disintegrated and collapsed, decreasing the number of

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