WATER QUALITY AND HEAVY METAL PROSPECTIVE AT PENGKALAN CHEPA RIVER BASIN, KELANTAN

MOHD SAIFUDDIN BIN MALIKI @ ABDULLAH

UNIVERSITI SAINS MALAYSIA

2020

WATER QUALITY AND HEAVY METAL PROSPECTIVE AT PENGKALAN CHEPA RIVER BASIN, KELANTAN

by

MOHD SAIFUDDIN BIN MALIKI @ ABDULLAH

Thesis submitted in fulfilment of the requirements

for the degree of

Master of Science

October 2020

ACKNOWLEDGEMENT

Bismillahirrahmanirrahim. In the name of Allah, all praises and thanks be to him, the most gracious and the most merciful. First of all, I would like to express my deepest appreciation and sincere gratitude to my main supervisor, Dr. Maliki Hapani for his continually conveyed the spirit of adventure regarding research. I feel indebted for his guidance and persistent supports, advice and constructive comments that helped me in completing this project. My sincere appreciation and acknowledgment to my co-supervisor, Dr. Nur Fatien Muhamad Salleh for her warm and valuable opinion, guidance and advice on this project. My gratitude is extended to Laboratory Science Officer, Mr. Md. Khairul Azuan Che Azid and Mr. Wan Mohd Sahnusi Wan Alias for kindly cooperation in this project. My very profound gratitude to my parents Mr. Maliki Daud and Wan Kelsom Wan Ibrahim and to my wife, Jamilah Ahmad Zabidi for providing me with unfailing support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis. Last but not least, the acknowledgment is considered incomplete without thanking all the USM staff, colleagues, friends and everybody who have been given great help and supports directly or indirectly to the successful completion of this thesis. This accomplishment would not have been possible without them. Thank you.

TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

Page

LIST OF PLATE

ABBREVIATIONS

AAS	Atomic Absorption Spectrometry
APHA	American Public Health Association
BOD	Biological Oxygen Demand
Cd	Cadmium
COD	Chemical Oxygen Demand
Cr	Chromium
Cu	Cuprum
DDE	Dichlorodiphenyldichloroethylene
DID	Department of Irrigation and Drainage
DO	Dissolved Oxygen
DOE	Department of Environment
DOSM	Department of Statistics Malaysia
EQR	Environmental Quality Report
Fe	Ferum
HNO_3	Acid citric
INWQS	Interim National Water Quality Standard
IQR	Interquartile range
Km	Kilometre
mg/L	milligram / Liter
MMD	Malaysian Meteorological Department
MOH	Ministry of Health
MPKB	Municipal Council of Kota Bharu
NDWQS	National Drinking Water Quality Standard
NH_3	Ammonia

NH_3-N	Ammoniacal Nitrogen
NH_4+	Ammonium
PCR	Pengkalan Chepa River
PCRB	Pengkalan Chepa River Basin
pH	Power of Hydrogen
SIBOD	Sub Index BOD
SISS	Sub Index SS
SPAN	National Water Services Commission
SPSS	Statistical package for Social Science
SRA	Sustainable Rivers Audit
SS	Suspended Solids
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
USEPA	US Environmental Protection Agency
WQI	Water Quality Index

PROSPEKTIF KUALITI AIR DAN LOGAM BERAT DI LEMBANGAN SUNGAI PENGKALAN CHEPA, KELANTAN

ABSTRAK

Malaysia adalah sebuah negara yang pesat membangun sejak merdeka pada 1957, dari ekonomi rural kepada sektor ekonomi pembuatan berasaskan ekspot. Pada 2017, didapati 54% dari keseluruhan sungai dikesan tercemar akibat aktiviti antropogenik. Lembangan Sungai Pengkalan Chepa (LSPC) terletak di kawasan membangun dalam Daerah Kota Bharu. Kajian ini dijalankan untuk menentukan status kualiti air di LSPC berdasarkan Indeks Kualiti Air (IKA) dan kepekatan logam berat di dalam air sungai. Sampel air diambil dari sebelas stesen persampelan di sepanjang lembangan sungai dan dianalisis menggunakan YSI 556 MPS untuk ujian *in-situ* dan analisis makmal untuk ujian *ex-situ*. Kepekatan logam berat pula dianalisis menggunakan AAS. Persampelan air dijalankan bermula November 2018 hingga Jun 2019 yang meliputi musim lembap dan kering. Hasil kajian menunjukan jumlah nilai median untuk PCRB; DO (2.72 mg/L), BOD (6.42 mg/L), COD (33.5 mg/L), NH_3-N (1.02 mg/L), TSS (27 mg/L) dan pH (6.97). Berdasarkan WQI, PCRB diklasifikasikan di bawah Kelas III untuk kedua-dua musim dan dianggap sebagai sedikit tercemar. Kepekatan logam berat di dalam air sungai mengikut turutan Fe> Cr> Zn> Cu> Cd. Hampir kesemua logam berat didapati mematuhi had yang dibenarkan oleh garis panduan Kualiti Air Minum Kebangsaan (GKAMK) kecuali Cd. Ujian Kruskal Walis menunjukkan perbezaan yang signifikan antara parameter DO, BOD, COD, NH_3-N dan pH dengan lokasi persampelan ($\rho < 0.05$). Berdasarkan kajian ini dapat disimpulkan kualiti air LSPC adalah tercemar berdasarkan aspek DO, BOD, COD, NH_3-N, dan Cd.

WATER QUALITY AND HEAVY METAL PROSPECTIVE AT PENGKALAN CHEPA RIVER BASIN, KELANTAN

ABSTRACT

Malaysia is a rapidly growing developing country since independence in 1957, from a rural economy to an export-based manufacturing economy. In 2017, 54% of rivers found polluted due to anthropogenic activities. Pengkalan Chepa River Basin (PCRB) is located in a developing area in Kota Bharu district. This study was to determine the water quality status at PCRB based on Water Quality Index (WQI) and heavy metal concentration in river water. Water samples were collected from 11 stations along the river and analyzed using YSI 556 MPS for *in-situ* test and laboratories analyzed for *ex-situ* test. Meanwhile, heavy metal concentrations were analyzed using AAS. Water sampling was carried out starting from November 2018 until Jun 2019, covering wet and dry seasons. The finding shows total median value for water quality parameters; DO (2.72 mg/L), BOD (6.42 mg/L), COD (33.5 mg/L), NH3-N (1.02 mg/L), TSS (27 mg/L) and pH (6.97). According to WQI, PCRB was classified under Class III for both seasons and considered as slightly polluted. Concentration of heavy metals in water followed the order, Fe > Cr > Zn > Cu > Cd. Almost all the heavy metals were found within the permitted level by the National Drinking Water Quality Standard (NDWQS) except for Cd. Kruskal Walis test shows a significant difference between parameters (DO, BOD, COD, NH3-N and pH) and sampling locations ($\rho < 0.05$). Based on this study, it can be concluded that the water quality of PCRB is polluted based on DO, BOD, COD, NH3-N and Cd aspects.

CHAPTER 1

INTRODUCTION

1.1 Study Background

Rivers are the most essential freshwater resources for humans. Rivers are the sources of natural water which serves as a source for drinking water, irrigation, and fishing. Generally, rivers are essential for geology, biology, history, and culture. About 0.0001% of the total amount of water in the world represent rivers. Rivers provide not only for a habitat, nourishment, and means of transport to most organisms but also as an essential source of valuable deposits of sand, gravels and even for electrical energy (Anhwange *et al.*, 2012). Rivers are precious not only for humankind but also essential for the ecosystem as a whole.

There are about 189 river basin systems containing approximately 1,500 rivers in Malaysia with an estimated overall total length of 57,300 km. In Peninsular Malaysia, there are about 89 river basins that are mostly originating from the central mountain range, the Titiwangsa Range. Pahang River is the longest rivers (470 km long), followed by Kelantan River (400 km long) and the Perak River (240 km long) (Azwad, 2019). There are 25 rivers in Kelantan State, Malaysia. Seven rivers have a major basin namely Galas, Kelantan, Golok, Semerak, Pengkalan Chepa, Pengkalan Datu and Kemasin river basins. Kelantan River is the largest river in Kelantan and second-largest river in Peninsular Malaysia.

Pengkalan Chepa River Basin (PCRB) located in Kota Bharu District, Kelantan State, Malaysia and flows through the urban area from Kota Bharu city to the rural area near the Sabak coastal. PCRB formed by the junction of Kelantan River and Pengkalan Chepa River and flowed over about 12 kilometres into the South China Sea. PCR has divided by three-stream flows namely Keladi River, Pengkalan Chepa River and Tok Sadang River comprise from six tributaries, namely Alor A, B, C, D, Kok Pasir and Alor Lintah (DOE, 2017).

Pengkalan Chepa River subjected to urban development and crowded area. Pengkalan Chepa River receives point pollution loads from sewage treatment as well as major industries including textiles and manufacturing factories which located near the riverbank. The non-point pollution source in the study area contributed to domestic drainage and land run-off. In some places, the streams in the Pengkalan Chepa River is used for rubbish dumping sites (Rohasliney, 2011).

The anthropogenic commotion of the land surface and deteoriations to the river systems increase the rates of water consumption that are adversely impacted the quality of freshwater resources throughout the world (Singh and Kalamdhad, 2011). The decline in clean rivers is due to the increase in the number of polluting sources near the riverbank. Biochemical Oxygen Demand (BOD) and Suspended Solids (SS) remained to be major influence in river pollution. High BOD level can be caused by inadequate treatment of sewage of effluent from agro-based and manufacturing industries. The primary sources of NH_3-N usually came from livestock farming and domestic sewage (DOE, 2017).

Thus, this thesis is aiming to evaluate the ecosystem health status of this river. Water quality parameters such as pH, dissolved oxygen, BOD, COD and NH_3-N are essential indicators for the ecosystem health evaluation, hence determine damage to waterways attributed by human activity. A significant deviation of these parameters from 'natural' levels can result in ecosystem degradation and may impact environmental qualities and beneficial uses.

1.2 Problem Statement

Rivers are most vulnerable to pollution since they became an easy passage for the discharge of varying domestic, commercial, industrial and agricultural effluents because of their natural function as drainage channels. For the last three decades, Malaysia has developed very rapidly with urbanization increasing many folds in all major cities and town. The river systems become overstressed, resulting from all these developments. Swift development has produced enormous amounts of human wastes as well as from anthropogenic activities such as agriculture, industrial, commercial, and transportation wastes. This situation causes the exacerbation of the occurrence of low flows. As a result, many rivers are polluted, some extent of not rehabilitating (Huang *et al.*, 2015).

Water pollution can be defined as the condition of water bodies that contain various elements in it. Measuring and studying the elements contained in the water allows the water to be identified as pure water, clean and contaminated (Nasir *et al.*, 2012). A river is said to be polluted when pollutants affect the quality of the water involved. Contamination defined as environmental quality changes caused by human action that produce adverse effects (Hodges, 1973).

Water quality evaluation was first started in the mid-1960s and was widely promoted and developed in the 1970s. At first, water quality evaluation limited to the detection of pH, dissolved oxygen, and a few relatively common projects such as E. coli. Then, with the development of more severe pollutants, water quality monitoring gradually increased into surveillance programs. For example, at present, the US Environmental Protection Agency (USEPA) regulates more than 100 water quality monitoring projects. The number of water quality evaluation methods has also grown. In 1965, R.K. Horton put forward the first water quality index (WQI) (Liu *et al.*, 2014).

Since 1950s, parallel with the growth of industry and human population, the water pollution became the worldwide issues. Aquatic life and living environments have been affected, and water safety threatened. With the growing imbalance in the supply and demand for water resources, water quality issues have been enlightened, leading to the development of effective water quality evaluation methods.

River pollution nationwide increased slightly by 2 per cent in 2017, compared with 2013, according to a study by the Department of Environment. Eleven percent of main river basins were considered polluted from 189 main river basins in 2017. Irrigation and Drainage Department (DID) Malaysia launched the Integrated River Basin Management programme nationwide. This programme to ensure that there is enough water clean water, as well as reduce the risk of floods and increase environmental conservation (The Star, 2018).

Usually rivers in Malaysia, especially located in urban area are heavily polluted with pollution by chemicals, organics and solid wastes. The disturbances and contamination of this pollution will eventually flow down to the estuaries and accumulate before getting into the sea. The Department of Environment (DOE) continues the river water quality monitoring programme to determine the status of river water quality and to detect changes in river water quality. Water samples were collected at regular intervals from designated stations for in-situ and laboratory analysis to determine its physic-chemical and biological characteristics. Out of the 477 rivers monitored, 219 (46%) were found to be clean, 207 (43%) slightly polluted while 51(11%) polluted in 2017 (Figure 1.1)(DOE, 2017).

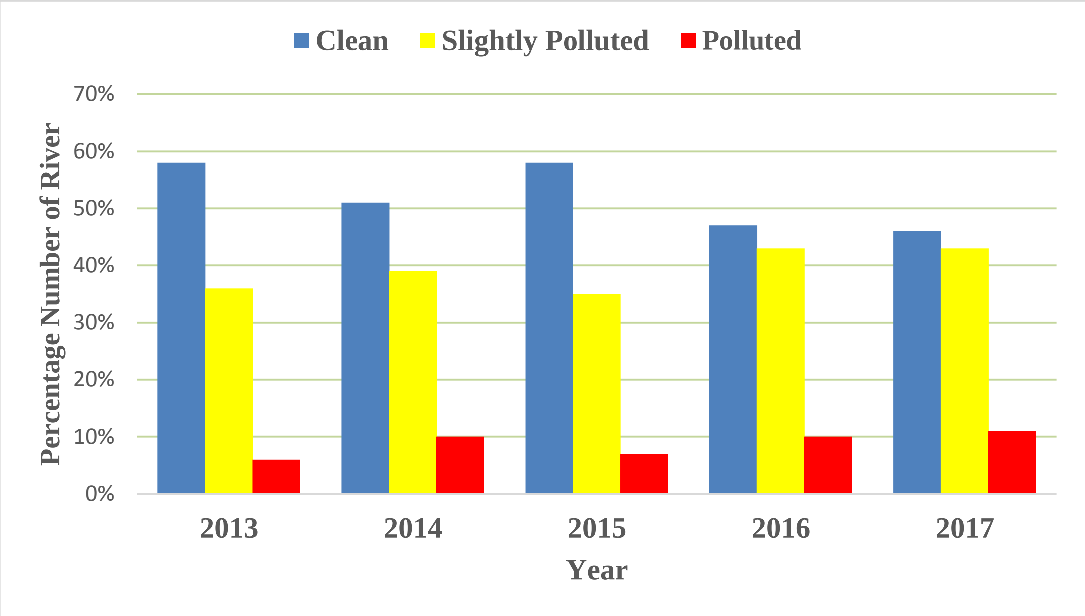

Figure 1.1 Malaysia River Water Quality Index (WQI) Trend for 5 years period. [Source: Environmental Quality Report 2017 by DOE]

The river water quality in terms of WQI had shown a slight decrease in 2017. The percentage of clean rivers has decreased to 46% in 2017 compared to 47% in 2016. The rate of the polluted river has slightly increased from 10% to 11% in 2017. In term of BOD sub-index, none of the monitored rivers was categorized as clean in 2017 (Figure 1.2). The number of polluted rivers in terms of BOD sub-index has decreased from 404 in 2016 to 336 rivers in 2017. The degradation of river water quality in terms of BOD may have been attributed to various sources of organic pollutants, including wastewater from domestics, industrial, and commercials activities (DOE, 2017)

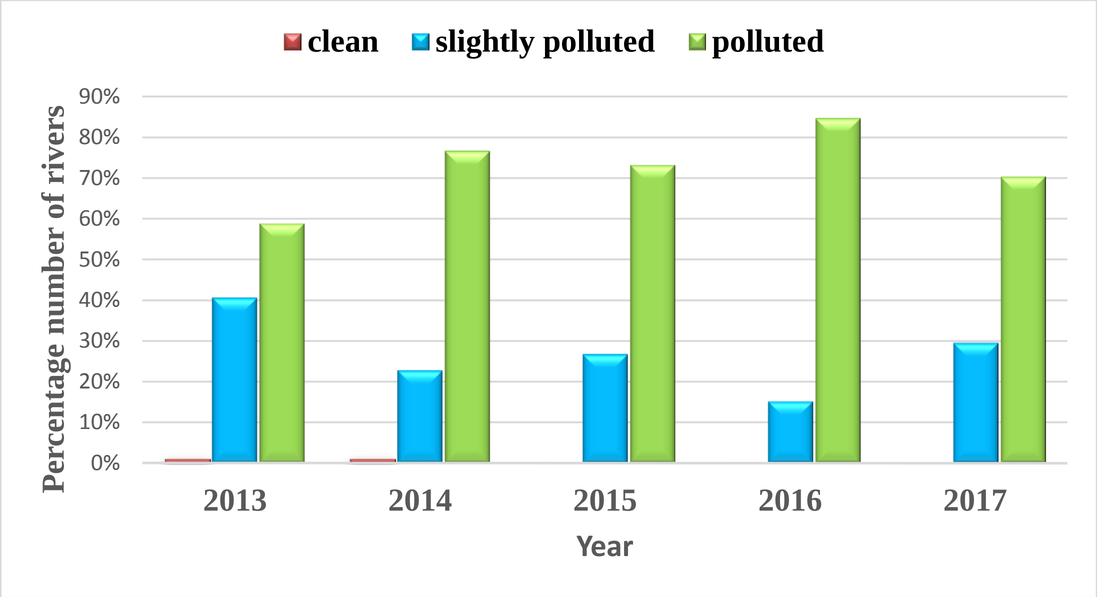

Figure 1.2 Malaysia: River Water Quality Trend Based on BOD for 5 years period. [Source: Environmental Quality Report 2017 by DOE]

Based on NH_3-N sub-index, the number of clean rivers has decreased from 115 in 2016 to 87 rivers in 2017, meanwhile the number of polluted rivers has increased from 149 in 2016 to 158 rivers in 2017 (Figure 1.3). The degradation of river water quality caused by NH_3-N can be associated with the continuous discharge of treated and untreated sewage into the rivers (DOE, 2017).

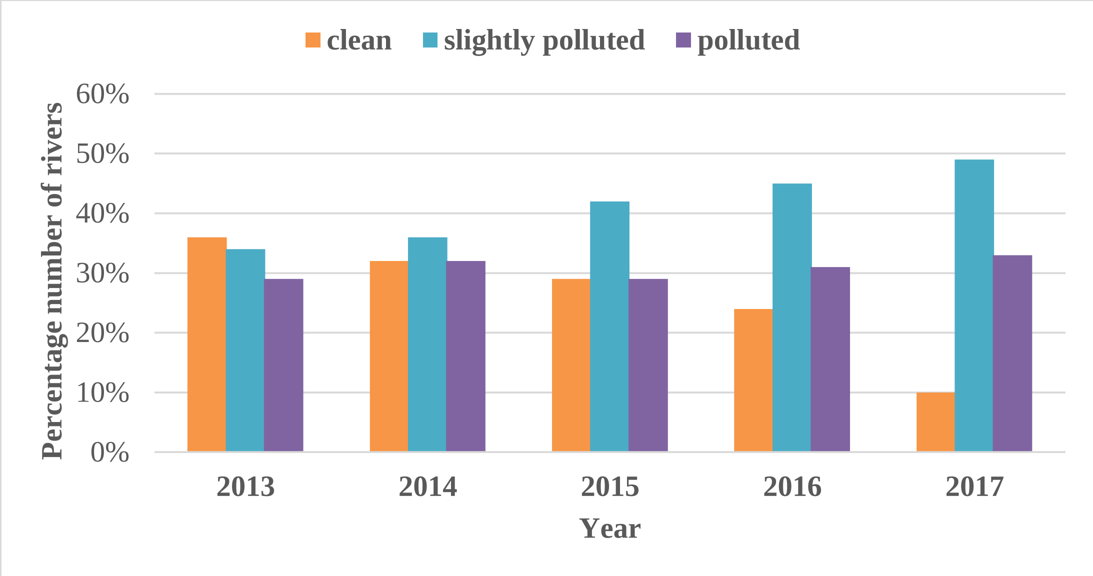

Figure 1.3 Malaysia: River Water Quality Trend Based on NH_3-N for 5 years period.
[Source: Environmental Quality Report 2017 by DOE]

In term of SS sub-index, the number of clean rivers has decreased from 295 in 2016 to 245 in 2017 (Figure 1.4). The number of polluted rivers in terms of SS sub-index has increased to 127 compared to 99 rivers in the previous year. The deteriorations in river water quality due to suspended solids pollution can be attributed by inefficient control against antrophogenic activities related to improper earthworks and land clearing (DOE, 2017).

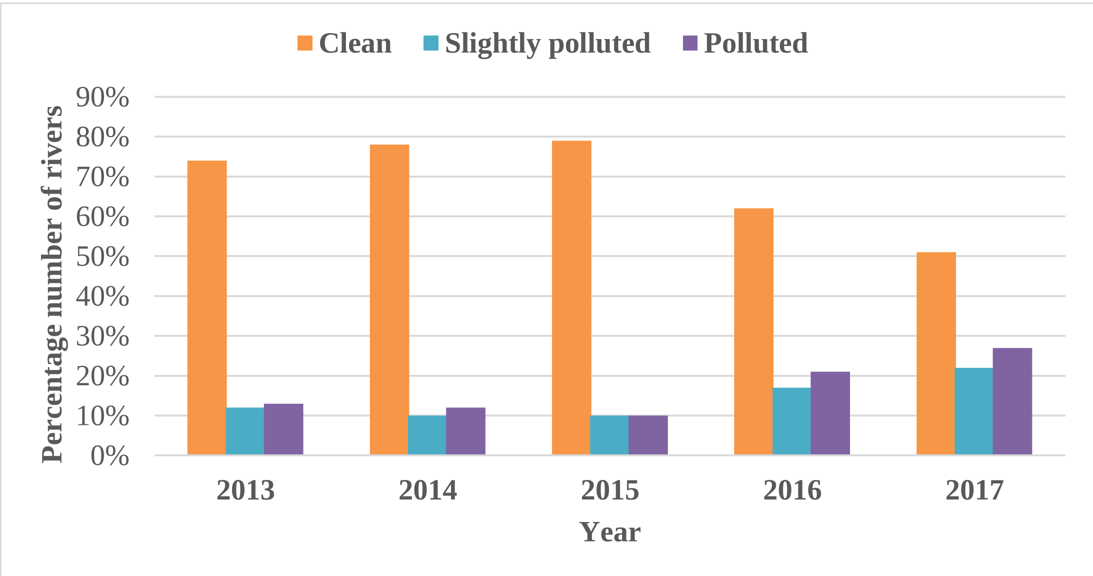

Figure 1.4 Malaysia: River Water Quality Trend Based on SS for 5 years period.
[Source: Environmental Quality Report 2017 by DOE]

Organic pollutants will contaminate the river through the sewage. This led to the accumulation of harmful bacteria and virus that may affect the aquatic organisms' reproductive abilities. Sewage pollution also causes water-borne diseases such as cholera, typhoid and hepatitis A that are harmful to human. Many types of pollutants post health hazards to human and aquatic life such as heavy metals, pesticides and herbicides. Consumption of aquatic life containing heavy metal pollutants results in reduced life spans and risky to get cancer. Pesticide and herbicide contamination are also harmful to fertility and growth of human and aquatic life (Azwad, 2019).

Once a river is polluted or damaged either by physico-chemical or heavy metal pollutant, recovering will involve high costs and require the involvement of many parties. The effort to restore the clean, origin quality of the river will take a very long time (Astro Awani, 2018). Drainage and Irrigation Department State make a cleaning work on substantial polluted Klang River start on 2011 and is expected to be fully completed by December 2020. The river cleaning project cost of 3.36 billion for this 110 km long river (Malaysiakini, 2019). Ultimately, once the river is polluted, it isn't elementary to recover it. Preventive measures are crucial before it's too late.

In March 2019, Malaysia was shocked when 2,775 people were given medical treatment and seven in the ICU in Pasir Gudang. Toxic fumes stemming from dumped toxic waste in Kim Kim River caused 111 schools closed. These toxic fumes were stemming from dumped toxic waste into Sungai Kim Kim. The patients complained of dizziness and shortness of breath after exposure to the toxic fumes. The investigations by the Department of Environment showed that exposure from organic solvents Benzene, Toulene, Xylene, Ethylbenzene and D-Limonene. This river pollution cost the government RM 6.4 million for cleaning works and compensation to the victims (Borneo Post, 2019). Generally, developing countries facing the challenge to reduce heavy metals pollutions because of their limited financial capacities to use advanced technologies (Chowdhury *et al.*, 2016).

Pengkalan Chepa River (PCR) is the main river whose take the municipal sewage from Kota Bharu City. Study of surface water pollution of this river is essential due to effluents from point source and non-point source which may risky in extensive deteriorations in the water quality. In this study, the water quality parameters and heavy metal concentration were measured and classified based on the National Water Quality Standard (NWQS) and National Drinking Water Quality Standard (NDWQS) respectively.

The other main factors that concern is the possibility of contamination between river pollution and groundwater supply in the surrounding area. The pollutant in surface water will potentially affect the water quality of nearest groundwater. There is a spatial relationship between river water and groundwater water quality (Shinde *et al.*, 2016). The surface water quality is strongly influenced by exchange of groundwater between the central pond and its moist margin (Hayashi *et al.*, 2016). According to National Water Services Commission (SPAN), Kelantan has the worst water services coverage in Malaysia as from the year 2012 to 2013 at urban and rural areas are 59.5% and 63.4% coverage respectively compared to more than 90% for national coverage. Since access to the piped water supply is limited, people tend to construct private water supply such as protected springs, tube wells and open wells. Extensive pumping, in a high-density populated area due to the high demand for groundwater supply will cause the water level to decline lower than the surrounding area (Zawawi *et al.*, 2010). Thus, this study is essential to determine the water quality of Pengkalan Chepa River Basin because it risky to affected the nearest groundwater that used for drinking.

Observation along these river shows there are fishing activities were spotted on. Fishes caught for a food source and income. Besides the popular edible fish species like Lampam Sungai (Barbonymus schwanenfeldii) and Jelawat (Leptobarbus hoeveni), freshwater prawns, crab and clam are also primary food sources derived from rivers. This catch sold in the nearest markets, including Wet Market Siti Khadijah in Kota Bharu. Therefore, it is crucial to study the degree of pollution in the river and determine the pollution causes, hence provide the suitable solutions in order to save the river water quality.

1.3 Objectives

1.3.1 General Objectives

To study the water quality at Pengkalan Chepa River basin by evaluation of physicochemical and heavy metal parameters through field and laboratory experiments.

1.3.2 Specific Objectives

1.3.2(a) To determine Water Quality Index (WQI) and the heavy metals concentration in Pengkalan Chepa River Basin

1.3.2(b) To compare median of physicochemical parameters with location of sampling stations

1.3.2(c) To compare median of heavy metal concentration with location of sampling stations.

1.3.2(d) To compare the level of Water Quality Index (WQI) with wet and dry season.

1.3.2(e) To compare the heavy metals concentration with wet and dry season.

1.4 Hypothesis

1.4.1(a) H_o: There is no significant different between physicochemical parameters status with location of sampling station

1.4.1(b) H_A: There is significant different between physicochemical parameters status with location of sampling station.

1.4.1(c) H_o: There is no significant different between heavy metals concentration status with location of sampling station.

1.4.1(d) H_A: There is significant different between heavy metals concentration status with location of sampling station.

1.4.1(e) H_o: There is no significant difference between Water Quality Index (WQI) status during wet and dry season

1.4.1(f) H_A: There is significant different between Water Quality Index (WQI) status during wet and dry season

1.4.1(g) H_o: There is no significant difference between heavy metals concentration status during wet and dry season

1.4.1(h) H_A: There is significant difference between heavy metals concentration status during wet and dry season

1.5 Significance of The Study

On a daily basis, human activities like an industrial, agricultural and residential cause vast quantities of natural and synthetic chemical to be emitted into the atmosphere including into surface water. Water is essential, and it is life to all living organisms. Without water, life will be short-lived. The value of water is in both quality and quantity.

Malaysia is sacred with abundant natural resources and a climate conducive to accommodate cultivation of commercial crops such as rubber and palm oil. Malaysia has become dominant world producer in rubber, palm oil and cocoa. Along with the emphasis on agricultural development in the 1960s and 1970s, pollution from the agro-based industries contributed 90% of the industrial pollution load. The agro-based industries were the largest source of water pollution during a period when there were insufficient provisions for regulating the discharge of effluents (DOE, 1991).

Historically, water pollution scenario in Malaysia has started with the beginning of agriculture in Malaysia in the early 1970s (Jamaluddin, 2000). The agricultural sector development was important to the overall economic development of the country as its growth on that time. This sector contributed to one third of the Gross Domestic Product (GDP) provided for half of the total employment and 50% of the foreign exchange earnings (Indrani *et al.*, 2001). Malaysia experienced constantly changing development since independence in 1957, from a rural economy based on agriculture and tin mining to an export-based manufacturing economy. Urbanisation and industrialisation was rapidly transformed over the last three decades (Ooi, 1979).

Quality is essential for maintaining good health. Poor quality water is subject to bring all types of health and disease problems. The study of river water pollution is essential due to effluent from anthropogenic activities which discharge into the river resulting in extensive alterations in the water quality. Generally, most of the anthropogenic activities pose a harmful threat to aquatic ecosystem in the river and the quality of river water that being used as domestic supply (Al-Badaii *et al.*, 2013).

Pengkalan Chepa River Basin (PCRB) is affected by urban development and accommodates crowded and dense population due to its location in the urban area. There are residents around the PCRB using the groundwater source for drinking and their living needs. There is a possibility the pollution from the PCRB contaminates the groundwater. The catching fish activities for human consumption is active along this river. The pollutant will transmit to people from fish consumption and the contact with river water. Failure to provide adequate protection and effective treatment will expose the river to the pathogen pollution. Hence, it will risk community and environment health status.

In addition, none studies on heavy metals concentration in river water samples were conducted before in PCR. The previous heavy metal study by Chuan *et al.* (2017a) was using marsh clam as heavy metal bio-indicator in PCRB. Massive flood events occurred in 2014 at Kelantan brought enormous damage to the surroundings and also substantial damage to the cities' infrastructures. During flood events, much raw sewage which was untreated could enter the Kelantan River, which can cause contamination from heavy metals. This study also was intended to determine the pollution level on water quality of PCR, and the sources from the land used that contribute to the deterioration of water quality in this study area. The findings will be useful to create awareness among people and help authorities to take appropriate steps for maintaining water quality of this river. Besides, it also helps to provide information on the current condition of this river to another comprehensive study on the future.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The river plays a significant role for the community, specifically in fisheries and water supply for human need. The continuous increase in socio-economic activities in this area, accompanied by even faster growth in pollution stress on river quality. One of the challenges in evaluating and improving water quality is the many different factors affecting water quality. Generally, water provide immerse importance in geology, biology, history and culture apart from serving as a source of drinking water, irrigation and fishing (Anhwange *et al.*, 2012).

According to Environmental Quality Act 1974 (2006), pollution means any direct or indirect alteration of the physical, thermal, biological or radioactive properties of any part of the environment by discharging, emitting or depositing to wastes so as to affect any beneficial use adversely, to cause a condition which was hazardous or potentially hazardous to public health, safety, or welfare, or to animal, birds, wildlife, fish or aquatic life, or to plants or to cause a contravention of any condition.

River Water quality is affected by air quality, pesticides and toxics. Airborne pollutants such as nitrogen and sulphur compounds do not unravel; they still remain or change their chemical structure with the reaction of other substance. These pollutants will permeate into the river through the formation of acid rain (USEPA, 2013). Regarding FAO (2017), agricultural use of pesticides is a toxic chemical that released into the environment. These toxic substances contain heavy metal may give a significant impact on water quality and leads to serious environmental consequences. Industrial wastes are known to affect natural life by direct toxic action adversely or indirectly through qualitative alterations in the character of the water as well as that of the stream bed.

2.2 Water Quality Standard for river

The assessment of river quality and the classification of the river into the number of classes in Malaysia based on the Interim National Water Quality Standard (INWQS) adopted by DOE. DOE has been consistently monotoring the rivers in Malaysia since year 1978 (DOE, 2019). WQI is a measurable instrument used to convert various readings of water characterization data into a water quality level and that describing overall water quality status (Li and Liu, 2019).

Water Quality Index (WQI) expresses the quality of water via a single number by combining measurements of selected physical and chemical parameters method (DOE, 2017). Generally, WQI is a unitless number that varies between 0 and 100. A higher index value represents a clean water quality level (Cude, 2001). Therefore, a numerical index is widely used as a management tool in water quality assessment worldwide (Chee, 2018).

WQI is a set standard of parameters used to evaluate the quality of river water. The WQI takes into consideration six critical parameters which is DO, BOD, COD, NH_3-N, TSS and pH (DOE, 2017). The functions of each parameter are listed down in Table 2.1.

Table 2.1 Significance of each parameter listed in DOE-WQI

Parameter	Functional Description
pH	Measure of contamination and acidity
BOD	Determination of oxygen consumption rate by biological organisms in water.
COD	Identification of the amount of organic pollutants in water.
NH_3-N	Indication of nitrogen-based nutrient present in water.
TSS	Present of tiny solid suspension as colloids in water.
DO	Amount of oxygen dissolved in water.

Throughout the years, the critical parameters identified to be affecting the quality of river water significantly are Biochemical Oxygen Demand (BOD), Ammoniacal Nitrogen (NH_3-N) and Total Suspended Solid (TSS) (DOE, 2017).

2.3 Physicochemical Parameters

Present information about the concentration of various solutes at a specific place and time is provided from water quality assessment. From the information provided, the basis of suitability of water for its designated uses can be determined, and the existing conditions can be improved. Besides that, current information required in assessing water quality for optimum development and management for the beneficial uses (Lloyd, 1992).

The introduction of water classification is to assist the authorities in controlling and enforcing rules stated under the Environmental Quality Act 1974. Besides that, it is used to facilitate the standardization of water quality parameters assessment throughout the country. Every year, the classification of river water is implemented based on WQI and INWQS which are Class I, II, III, IV and V. Six main water parameters used in the derivation of WQI are DO, BOD, COD, NH_3-N, TSS and pH.

2.3.1 Dissolved Oxygen (DO)

The DO is among the crucial parameters regarding water quality. The amount of DO indicates the status of pollution of that water. The amount of the DO is essential to clarify whether a river system is predominantly aerobic or anaerobic, thus predict aerobic biological processes based the biodegradable organic transforming in water. The DO decreased when oxygen was consumed by aerobic microorganisms during process metabolic degradation of organic discharge. The presence of dissolved oxygen is essential for the self-cleansing of the river water system. The DO levels depend on temperature, dissolved salts, atmospheric pressure, suspended matter, and living species.

The presence of microorganisms and biodegradation processes affect the DO level as well. Stratification area decreasing DO in the water column in lakes, large deep rivers, or the ocean. By contrast, DO increase in water flow like waterfalls or rapids, and decrease in the slow-moving portions of the river and those with organic discharges or microbial activity. Since the dissolution of air in water is an interface mass-transfer phenomenon, the degree of contact and of mixing with water is also essential (Ibanez *et al.*, 2008).

2.3.2 Biochemical Oxygen Demand (BOD)

The Biochemical Oxygen Demand (BOD) is among the most commonly used criteria for water quality evaluation. It provides data about the ready biodegradable fraction of the organic load in water (Jouanneau *et al.*, 2014). BOD test for evaluating the amount of dissolved oxygen used by aerobic biological organisms in the water sample to break down organic material present at a certain temperature over a specific time. The test took five days (BOD_5) of incubation at 20°C. BOD_5

used as a robust surrogate of the degree of organic pollution of water. The result commonly expressed in milligrams of oxygen consumed per litre. (YSI.com, 2019).

Oxygen is fundamental for aquatic life and plant in the river. Without free dissolved oxygen, rivers and lakes become uninhabitable for most aquatic life. Therefore, organic pollutants requiring oxygen for their decomposition may exert the most direct and the fastest influences on the ecology of these environments (Lee *et al.*, 1999).

Sources of BOD include mud, leaves and woody debris; animal compost; effluents from pulp and paper mills, wastewater treatment plants, feedlots, and food-processing plants; failing septic systems; and urban stormwater runoff. BOD is affected by the same factors that affect dissolved oxygen. BOD measures two readings; immediately dissolved oxygen (initial) amount, and the amount of dissolved oxygen remaining after five days(final). The amount of BOD represents the amount of oxygen consumed by microorganisms to break down the organic matter present during the incubation period (YSI.com, 2019).

2.3.3 Chemical Oxygen Demand (COD)

COD test is used to determine the amount of organic and inorganic oxidizable compounds in water samples, making COD a useful measure of water quality. It expressed in milligrams per litre (mg/L), which indicates the mass of oxygen consumed per litre of solution (JPS, 2009).

COD signify the amount of oxygen demand needed by dissolved matter, which is often used to characterize organic matter concentration. COD is one of the important water quality parameters because it was representing the depletion of dissolved oxygen. With high COD value, the dissolved oxygen content will reduce significantly, which will pose harm to the aquatic life. The conventional methods for evaluating COD however, require the time-consuming process of refluxing samples to achieve complete oxidation (Lee et al., 1999).

BOD appears to be the most fundamental element that affects the value of COD. COD and BOD process is dependent on each other as a chemical oxidation and reaction process transpire when microorganisms break down organic matter into a more stable form. Therefore, more oxygen consumed when the growth of microorganisms rises to lead to low DO together with and an increased BOD (Anita and Mawar, 2012).

2.3.4 Total Suspended Solid (TSS)

Suspended solids (SS) refers to the concentration (mg/L) of organic and inorganic matter, which remains in the water column of a stream, river, or lake by turbulence. SS typically are solid particles which have a size bigger than 2 microns found in water sample (Fondriest.com, 2018). SS are the major contributor to reduced water clarity and contains pollutants and pathogens. SS remain in suspension in a water body as a colloid or due to the motion of the water.

All streams or water body carry some SS under natural conditions. However, if concentrations are increase through anthropogenic perturbations, it leads to alterations to the physical, chemical and biological substances of the waterbody. Water quality effect caused by a high level of SS includes reduced penetration of light in water, temperature changes, and embankment of channels and reservoirs when suspended solids deposited. Generally, these physical alterations are associated with undesirable aesthetic effects (Lloyd *et al.*, 1987). These process consumed the dissolved oxygen then the consequences of critical oxygen shortage which can lead to fish kills during low-flow conditions (Ryan, 1991).

2.3.5 Ammoniacal Nitrogen (NH_3-N)

Determine Ammoniacal Nitrogen (NH_3-N) is a measure of the oxidized form of nitrogen in a water body and are an essential macronutrient for aquatic life. Nitrates can be harmful to human's health if contaminated. Human intestines break nitrates down into nitrites, which affect the ability of red blood cells to carry oxygen. Nitrites can also cause severe illnesses in fish (Davis and McCuen, 2005). Ammonia (NH_3) as a neutral molecule, can diffuse across the epithelial membranes of aquatic organisms much more readily than the charged ammonia ion. Ammonia could block oxygen transfer in the gills of fish. Fish suffering from ammonia poisoning appear sluggish and come to the surface of the water gasping for air (Luo *et al.*, 2015).

Temperature is one of the primary factor affecting the equilibrium between NH_3 and NH_4. At any pH, more toxic ammonia is present in warmer water than in colder water (YSI.com, 2019).

2.3.6 pH

The pH measurement is a measure of how acidic/alkaline of water body is. The scale goes from 0 to 14, with 7 being neutral. pHs less than 7 indicate the water body is acidic, whereas a pH of greater than 7 shows that the water body is alkaline. Specifically, pH measured the relative amount of free hydrogen and hydroxyl ions in the water. The acidic water body contains more free hydrogen ions, whereas alkaline water body has more free hydroxyl ions. Since pH can be altered by chemicals in the water, pH is an essential measurement of water quality indicator either the water was chemically changing. pH is reported in "logarithmic scale". Each scale number represents a 10-fold change in the acidity/basicness of the water. The water body with a pH of six is ten times more acidic than water having a pH of seven (USGS, 2019).

A pH indicates the contamination and acidification in a natural water system (Palaniappan *et al.*, 2010). The pH is an important parameter, as all chemical and biochemical reactions ruled by pH. The range of pH of water is essential for the biotic communities such as aquatic life and plant because a small change of pH will affect them, i.e. from slightly acidic to slightly alkaline condition (George, 1997). Generally, pH value influenced by carbon dioxide-bicarbonate equilibrium system in natural waters (Lalparmawii and Mishra, 2012). Since the pH of water body influences other chemical reactions such as solubility and metal toxicity, therefore it is vital in the determination of water quality (Fakayode, 2005).

2.4 Classifications of WQI for river water

The measurements of the six parameters mentioned above can be done either *in-situ* or analysis at the laboratory. There are two methods to evaluate the quality of river water, which are either grouping the water quality into various classes with specific ranges for parameters or calculating the WQI score to evaluate the water pollution status. Based on the six parameters listed in WQI, the quality of river water is categorised by the measurable ranges of the parameters in milligram per litre (mg/L) unit, with an exemption where pH is dimensionless. There are five classes of water quality based on National Water Quality Standards in Malaysia with the specifications, as stated in Table 2.2.

Table 2.2 Classifications of WQI for Malaysian river water

Parameter	**Unit**	**Class**				
		I	**II**	**III**	**IV**	**V**
NH_3-N	mg/L	<0.1	0.1-0.3	0.3-0.9	0.9-2.7	>2.7
BOD_5	mg/L	<1	1-3	3-6	6-12	>12
COD	mg/L	<10	10-25	25-50	50-100	>100
DO	mg/L	>7	5-7	3-5	1-3	<1
pH	-	>7.0	6.0-7.0	5.0-6.0	<5.0	>5.0
SS	mg/L	<25	25-50	50-150	150-300	>300
WQI		>92.7	76.5-92.7	51.9-76.5	31.0-51.9	<31.0

River classification was essential to identify the physical and chemical characterization of the river. The river needs to be classified so that the source of water can be determined either it was clean and appropriate for human needs. The suitability of the river uses classified according to Table 2.3. WQI calssifications can be used to determined on how the proper uses of river water. It summarized that WQI in range of 81 until 100 is categories as the clean river, range of 60 until 80 in slightly polluted and polluted river in WQI range of 0 until 59 (DOE, 2017).

2.4.1 Classification of water quality based on intended uses of river water

Different classes of water quality based on National Water Quality Standards (NWQS) in Malaysia are meant for different applications as stated in Table 2.3.