THE IMPACT OF ACIDIFIED PEAT SOILS ON WATER QUALITY AT SEMBRONG AND BATU PAHAT RIVER

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This Master's thesis, I wish to dedicate especially to my family;

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ABSTRACT

The water quality of Sembrong River and Batu Pahat River might be affected by acid sulphate soils (ASS) which resulted from pyritic peat soils. The effect of *pyrite* oxidation in peat soils releases large amounts of Al and Fe and can impact nearby river water in contact with the soil. Other factors that can impact water quality comprise sediment (minerals) run - off, which is one of the main aspects that influenced the water quality in Malaysia. This research aims to characterize water quality and acidified peat soils based on the physicochemical properties (for soils and water) and geochemical elements (for soils only), analyze the effect of acidified peat soils characteristics (physicochemical properties) on water quality, correlate the effects of the geochemical elements of acidified peat soils on the physicochemical properties of water. Characterization of peat soils and water quality comprises in-situ measurements and laboratory analysis. The variables tested for water quality parameters comprise heavy metals (Al, Fe and Zn), anions (NO_3^-, PO_4^{3-} and SO_4^{2-}), temperature, DO, TDS, pH, ORP and EC. The identification of physicochemical properties parameters for soils consist of heavy metals (Al, Fe and Zn), anions (NO_3^-, $PO_4^{3-}$and SO_4^{2-}) and pH whereas the geochemical elements of soils were based on the mineralogy presence in the peat soil. All of the parameters have been analyzed with ICP-MS, IC, SEM-EDX and XRD equipment and statistical method using ANOVA and correlation coefficients. The results revealed that high amounts of Al, Fe, SO_4^{2-} and the decrement of pH provides evidence of *pyrite* oxidations. The data from XRD analyses proven the occurrence of *jarosite* and other minerals in peat samples at both study areas which are also the outcomes and product of *pyrite* oxidation. SEM-EDX results depicted the most plentiful: SiO_2 > Al_2O_3 > Fe > *pyrite* > Zn and the maximum amount of SiO_2 and Al_2O_3 tends to increase the Al concentrations in water for both rivers. All of these outlines would declare that the acidified peat soils were naturally ASS which tends to impact the water quality for both selected sites in Batu Pahat, Johor.

ABSTRAK

Kualiti air Sungai Sembrong dan Sungai Batu Pahat mungkin terjejas oleh tanah asid sulfat (ASS) yang terhasil daripada tanah gambut piritik. Kesan pengoksidaan pirit dalam tanah gambut membebaskan sejumlah besar Al dan Fe dan boleh memberi kesan kepada air sungai berdekatan yang bersentuhan dengan tanah. Faktor lain yang boleh memberi kesan kepada kualiti air ialah larian sedimen (mineral), yang merupakan salah satu aspek utama yang mempengaruhi kualiti air di Malaysia. Penyelidikan ini bertujuan untuk mencirikan kualiti air dan tanah gambut berasid berdasarkan sifat fizikokimia (untuk tanah dan air) dan unsur geokimia (untuk tanah sahaja), menganalisis kesan ciri tanah gambut berasid (sifat fizikokimia) terhadap kualiti air, menghubungkaitkan kesan. unsur geokimia tanah gambut berasid pada sifat fizikokimia air. Pencirian tanah gambut dan kualiti air terdiri daripada pengukuran in-situ dan analisis makmal. Pembolehubah yang diuji untuk parameter kualiti air terdiri daripada logam berat (Al, Fe dan Zn), anion (NO_3^-, PO_4^{3-} dan SO_4^{2-}), suhu , DO, TDS, pH, ORP dan EC. Pengenalpastian parameter sifat fizikokimia bagi tanah terdiri daripada logam berat (Al, Fe dan Zn), anion (NO_3^-, PO_4^{3-} dan SO_4^{2-}), dan pH manakala unsur geokimia tanah adalah berdasarkan kehadiran mineralogi dalam tanah gambut. Kesemua parameter telah dianalisis dengan peralatan ICP-MS, IC, SEM-EDX dan XRD serta kaedah statistik menggunakan ANOVA dan pekali korelasi. Keputusan menunjukkan bahawa jumlah Al, Fe, SO_4^{2-} yang tinggi dan penurunan pH memberikan bukti pengoksidaan pirit. Data daripada analisis XRD membuktikan kejadian jarosit dan mineral lain dalam sampel gambut di kedua-dua kawasan kajian yang juga merupakan hasil dan produk pengoksidaan pirit. Keputusan SEM-EDX menggambarkan yang paling banyak: SiO_2 > Al_2O_3 > Fe > pirit > Zn dan jumlah maksimum SiO_2 dan Al_2O_3 cenderung untuk meningkatkan kepekatan Al dalam air untuk kedua-dua sungai. Kesemua garis besar ini akan mengisytiharkan bahawa tanah gambut berasid secara semula jadi adalah ASS yang cenderung memberi kesan kepada kualiti air untuk kedua-dua tapak terpilih di Batu Pahat, Johor.

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LIST OF SYMBOLS AND ABBREVIATIONS

Al	-	Aluminum
Al_2O_3	-	Aluminum Oxide
ANOVA	-	Analysis of variance
ASS	-	Acid Sulfate Soils
ASTM	-	American Society for Testing and Materials
BP1	-	Station 1 for Batu Pahat River
BP2	-	Station 2 for Batu Pahat River
BP3	-	Station 3 for Batu Pahat River
Cl	-	Chloride
°C	-	Degrees Celsius
DO	-	Dissolved Oxygen
EC	-	Electrical Conductivity
EPA	-	Environmental Protection Agency
Fe	-	Iron
Fe^{3+}	-	Ferric Ion
FeS_2	-	Pyrite
FKAAS	-	Fakulti Kejuruteraan Awam dan Alam Sekitar
FKMP	-	Fakuliti Kejuruteraan Mekanikal dan Pembuatan
FSTI	-	Fakulti Sains dan Teknologi Industri
g	-	gram
H^+	-	Hydrogen ion
H_2O	-	Chemical formula for water
IC	-	Ion Chromatography
ICP-MS	-	Inductively Couple Plasma-Mass Spectrometer
km	-	kilometer
L	-	Liter
m	-	meter

mg/L	-	Milligrams per Liter
mm	-	millimeter
MPRC	-	Micropollutant Research Centre
mV	-	millivolt
NO_3^-	-	Nitrate
ORP	-	Oxidation-reduction Potential
pH	-	Potential of Hydrogen
PO_4^{3-}	-	Phosphate
SR1	-	Station 1 for Sembrong River
SR2	-	Station 2 for Sembrong River
SR3	-	Station 3 for Sembrong River
S	-	Soils
SEM-EDX	-	Scanning Electron Microscope -Energy Dispersive Using X-Ray
Si	-	Silicon
SiO_2	-	Silicon Dioxide
SO	-	Silicon Oxide
SO_4^{2-}	-	Sulphate
TDS	-	Total Dissolved Solids
μ	-	Micro
μS/cm	-	Microsiemens Per Centimeter
UTHM	-	Universiti Tun Hussein Onn Malaysia
W	-	Water
Wt %	-	Weight Percent
XRD	-	X-ray Diffraction
Zn	-	Zinc

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CHAPTER 1

INTRODUCTION

1.1 Background study

Healthy river water is vital for the human population and aquatic life. Furthermore, rivers, ponds and groundwater are the major attributes of water resources (Tyagi and Sharma, 2014) in the world and nowadays, water quality becomes a very sensitive matter (Sánchez et al., 2007; Simeonov et al., 2003). The effect of human actions comprises industrial and agricultural projects (Delpla et al., 2009; Simeonov et al., 2003) and climate change comprises weathering of crustal substances and erosion (Simeonov et al., 2003), tends to decrease the quality of water (Delpla et al., 2009; Sánchez et al., 2007).

The condition becomes more serious when Malaysia is faced with river contamination problems (Chin and Ng, 2015). ASEAN Working Group for Water Resources Management AWGWRM (2013), revealed that there are 293 fully decontaminated rivers, 203 moderately contaminated and 74 contaminated rivers within Malaysia. Moreover, based on the distribution of water contamination sources from the country in Peninsular Malaysia, the highest was detected at 414 in Selangor, 384 in Johor, 328 in Penang and 253 in Perak, as previously reported by Muyibi, Ambali & Eissa (2008). All of the data shows that the water quality is getting worse in Malaysia. Moreover, the eroded soils can be the sediments within streams which are viewed as contaminant substances in water and sediment run-off is one of the main aspects that influenced the water quality in Malaysia (Abdullah, 1995; Amneera et al., 2013).

Peat soils are one of the popular soils for cultivation activities. Throughout the past two centuries, the area and intensity of cultivation manufacture on peat ground have become bigger in many nations (Lundin and Moors, 2008). Huat et al. (2011) revealed that peat ground with 6,300 ha is located within Pontian, Batu Pahat and Muar around West Johore. All vegetation in Batu Pahat district are surrounded by peat swamps (peatlands) and palm oil plantations (Ahmad et al., 2002). Furthermore, the biogeochemical system within peat bogs tends to the development a fresh mineral (sediment) appearance comprises of sulfides (pyrite, marcasite), carbonates (calcite), sulfates (gypsum, jarosite, anhydrite) and iron oxides (goethite) (Rudmin et al., 2018). Flows from agricultural soils (i.e. peat soils) might have impacted the nearby river water quality.

Water quality issues become more challenging these days (Mhlongo et al., 2018) due to contamination and minerals in the soils. Hence, monitoring and management are vital to making sure that water quality and resources will survive or continuously maintain (Misaghi et al., 2017). Furthermore, acquiring knowledge of the mineral (sediments) soils that influence the water quality of the river is crucial in the study.

This study aims to discover the water quality of the Batu Pahat River and Sembrong River according to the physicochemical and geochemical properties of peat soils. Humanly disturbed peat soils nearby the rivers, mainly through plantation and construction activities, might impact the surface water quality. To achieve the goal of this study, past research reviews are vital as the source and guideline, to know how the journey of peat soils can influence the river water. On-site measurement and laboratory analysis are beneficial to analyze the condition of water quality in the Batu Pahat River and Sembrong River as well as peat soil characteristics in the river surroundings. The outcomes of this study will provide a better understanding of identifying the impacts of peat soils on the nearby water quality. Safe and good quality river water will lead to a sustainable and environmentally friendly future for human beings as they consume the water, as well as other living things.

1.2 Problem statement

Pyrite minerals are one of the minerals that are present in peat soils. The effect of pyrite oxidation in peat soils releases large amounts of Al and Fe through the reactions that followed in the soil. The supply of Al and Fe from peat soil can impact nearby river water in contact with the soil. Furthermore, peat soils are known as acid sulphate soils (ASS). The minerals comprised of schwertmannite, ferrihydrite and jarosite (Fe(III) minerals) usually exist within ASS (Jones et al., 2009). Despite the several studies made on the properties of the soils in terms of its mineralogy (geochemical), there is still a lack of status and data on the effects of geochemical elements of acidified peat soils on the physicochemical properties of water.

For many years, the Sembrong River and Batu Pahat River are the main water resources in West Johor (Yong Peng, Batu Pahat and Kluang), Malaysia. The issue is, referring to Water Quality Index, unfortunately, Sembrong River is moderately contaminated (Awang et al., 2015) and Batu Pahat River experienced water quality problems (as shown in Figure 1.1). Moreover, Latiff et al. (2009) reported that the water quality of the Sembrong River might have been affected by ASS. One of the results of this impact is a fish fatality that has been linked to exposure to acid and Al from disrupted ASS (Ljung et al. 2009). Continuous problems from acidic water and heavy metals (Al) can deteriorate the water ecosystem.

However, to the best of our knowledge, there is no literature describing the effect of acidified peat soils characteristics on the water quality of Sembrong and Batu Pahat River by the focus on the physicochemical properties of water and soils based on pH, temperature, DO, TDS, EC, ORP, heavy metals and anions.

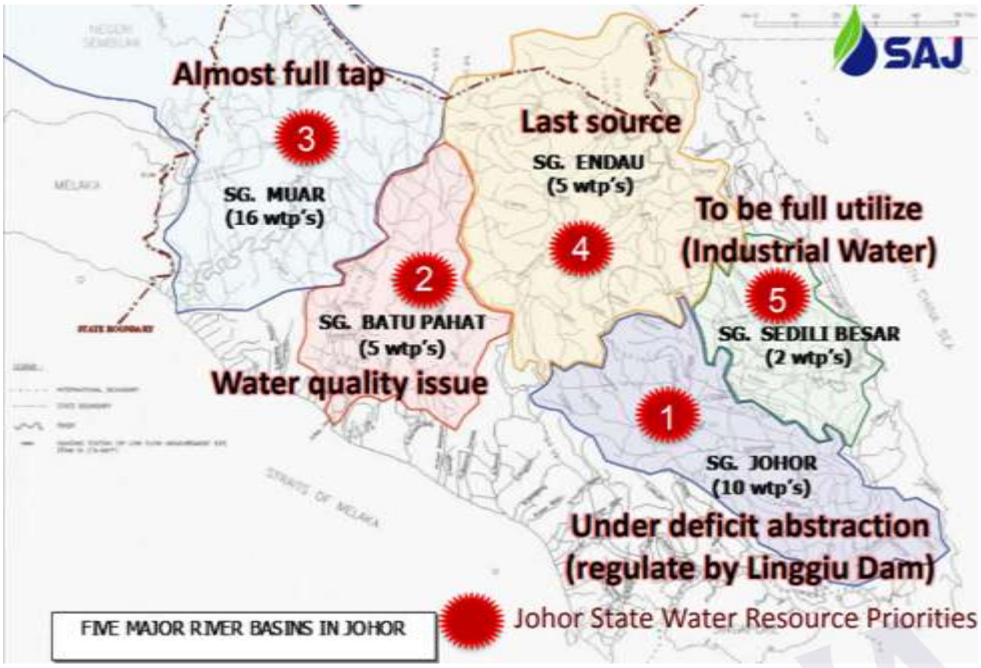

Figure 1.1: Water quality problems in the Batu Pahat River at five selected water treatment plants (SAJ, 2015)

Therefore, from all of the aforementioned facts, it is clearly shown that the elements in the soils have an essential relationship to nearby water quality. Understanding the relationship between the Sembrong River and Batu Pahat River systems is a crucial solution in controlling and managing their resources and catchment areas. Hence, a study has to be carried out to identify the aspects that may influence the water quality caused by toxic elements and minerals in acid sulfate affected soils that tend to mobilize into the river water.

1.3 Objectives of the study

The goal of this study is to identify the impact of acidified peat soils on water quality and how the system influences water quality. To accomplish the research goal, three objectives were outlined in this study. The objectives of the study are as below:

1. To characterize water quality and acidified peat soils based on the physicochemical properties (for soils and water) and geochemical elements (for soils only).
2. To analyze the effect of acidified peat soil characteristics (physicochemical properties) on water quality.
3. To correlate the effects of the geochemical elements of acidified peat soils on the physicochemical properties of water.

1.4 Scope of the study

The scope of the study covers only the area of Sembrong River and Batu Pahat River (located in Johor). The research focused on the surrounding soils (acidified peat soils) near the river that can impact the water quality of each river and the data collection of water quality was recorded during the site visit (in-situ measurements for water samples). The duration of the research study started in the year 2018-2019 period and the length of sampling points for each sampling for the chosen month was the same to get the finest results.

Besides, water samples had taken at chosen stations (sampling points) along the river for water quality analyses (laboratory analysis). The water sample of the river was characterized based on physicochemical properties and several parameters had chosen in this study: (a) Laboratory analysis: heavy metals (aluminium (Al), iron (Fe) and Zinc (Zn)), anions (nitrate (NO_3^-), phosphate (PO_4^{3-}) and sulphate (SO_4^{2-})), meanwhile for (b) In-situ measurements: pH, dissolved oxygen (DO), temperature, total dissolved solids (TDS), oxidation-reduction potential (ORP) and electrical conductivity (EC).

The surrounding acidified peat soil samples of the rivers were collected after rainfall events (limited to: 0.5m depth of peat soils at nearby cultivation area) to reveal the characteristics of the soils. The surveys of the peat soils were done at a distance estimated about 0.5 meters from the river (specifically: the soil in contact with the river).

Besides, the study was also concerned with the physicochemical properties of peat soils and the study parameters for peat soils samples consist of heavy metals (Al, Fe and Zn), anions (NO_3^-, PO_4^{3-} and SO_4^{2-}) and pH. The peat soil was also characterized based on its geochemical properties (mineralogy of the peat soils). In conclusion, the characteristics of soils are vital to investigate if the water quality was influenced by the peat soils.

This study was conducted at the Laboratory of Waste Water, Analytical, MPRC and FKMP at Universiti Tun Hussein Onn, Parit Raja, Batu Pahat, Johor and FSTI laboratory at Universiti Malaysia Pahang, Kuantan, Pahang.

1.5 Significance of the study

The outcomes of this study can provide insights into the interactions between elements (based on mineralogy and physicochemical) in peat soils and the quality of water. The contribution of this study can help to better understand the ecology of acidified peat soils and water quality, and therefore can increase the ability of water management for society, especially in domestic, industry and agriculture. Therefore, this study is an initiative to ensure water quality and surrounding soils can be properly managed at Sembrong River and Batu Pahat River, as both rivers are the main rivers to most Batu Pahat residents. The quantification of water quality and elements in the surrounding soils are essential in generating good water resources while also assisting in the management plan for both the Sembrong River and Batu Pahat River. This study is one of the strategies to ensure these two rivers are in satisfactory condition and therefore water sustainability for human beings, particularly in Batu Pahat can be achieved.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Past studies are crucial and required to help in demonstrating the literature studies related to this study. The previous studies helped to comprehend the idea and theory of the water quality (river) and the impact of nearby acidic surrounding soils on it. The concept of past research will serve as a guide for developing a literature review in terms of providing a beneficial resource so that the research will acquire a high-quality outcome.

This chapter discussed and revealed previous studies known to be relevant to the title of the research which is the impact of acidified peat soils on water quality. Past studies that explored water contamination as an impact of acidic soils are necessary to ease the course of this study. The foundation of the factors to water contamination by soils comprised of ASS, heavy metals, agricultural activities (human-made) and natural sources (weathering process).

The connection between research on soil composition and minerals in soils was also essential to discover the factors of geochemical features and the existence of physicochemical properties comprised of heavy metals and anions in soils that tend to pollute the water. This demonstrates how acidic soil travels can contaminate the rivers in the area.

2.2 Water

Water on the globe's surface exists with the appearance of rivers, ponds, and wetlands (Hamilton, 2005) and is very crucial to human being, ecosystems, and their food agriculture (Du et al., 2012). Currently, the quality of water is a truly sensitive topic (Simeonov et al., 2003), especially for rivers. Hence, water source managers experience the problem of making sure of the sustainability of water sources in the future (Iglesias et al., 2007).

As voiced out by Varol and Şen (2012), heavy metals transfer into streams from resources comprised of natural or human-made activities (agriculture) and some heavy metals within streams mostly originate from the weathering of rock and soils. Moreover, intensive cultivation increases erosion (after the weathering) and sediment load, which can unleash nutrients into the streams. Besides, several natural water bodies are normally acidic and poisonous metals, for example, Zn, exist in acidic water (Shinnie, 1982). Therefore, it is crucial to study this matter in depth, as mentioned by Islam et al. (2015), in predicting the possibilities of pollution as well as the mobility and bioavailability of substances according to the geochemical specification and classification of metals in a stream ecosystem.

Batu Pahat covers a population of 417,000 residents and the Batu Pahat River comprises eight waterways including the Sembrong River which is collected by two dams for water stocks (Bukari et al., 2015). Unfortunately, the main rivers in Batu Pahat such as the Sembrong River and Batu Pahat River have deteriorated in their quality of water. As revealed by Awang et al. (2015), the Sembrong River is moderately contaminated. Moreover, as early as the 1990s, the contamination of the Sembrong River was found to be deduced by a reduction in pH and increasing concentrations of heavy metals such as Al and Fe (Latiff et al., 2009). Thus, the Sembrong River and Batu Pahat River were selected as study areas in this study.

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