ASSESSMENT OF SEDIMENT AND WATER QUALITY IN SEMBRONG RESERVOIR, JOHOR

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I would like to dedicate this thesis to

My beloved father and mother,

Syed Hashim Bin Syed Endut

&

Saripah Norsidah Binti Syed Husin

Lovely brothers and sister,

Syed Putra Haizam Syed

Alhafiz

Syed Ahmad Shahir

Syed Ahmad Asyraf

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Supervisor and co-supervisor,

Dr Siti Hidayah Binti Abu Talib and Dr Muhammad Salleh Bin Hj Abustan

Thank you for your guidance, inspiration and motivation throughout this journey

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ABSTRACT

Sembrong reservoir is a major water source for 240,000 people in the district of Kluang and parts of Batu Pahat. Depletion of storage capacity due to the sedimentation process and eutrophication has recently been the most concerning issues at the reservoir. The objectives of this research are to analyze the distribution of sediment and sedimentation rate in Sembrong reservoir by using GIS. Also, to determine the sediment nutrients and trophic status index (TSI) in Sembrong reservoir in order to correlate the relationship between water and sediment nutrient parameters. Before conducting the laboratory testing, sampling process were done involving sediment and water sampling. Six (6) locations for sediment sampling were selected and portable gravity corer was used to get the sediment cores while for water sampling, seventeen (17) locations were chosen and samples were taken using grab method. Before conducted the laboratory testing, sediment cores were digested to change it state from solid to liquid. Laboratory testing for sediment samples consist of Total Nitrogen (TN), Total Phosphorus (TP) and sieve analysis for particle size distribution. For water samples, in-situ testing was conducted to test for the dissolve oxygen (DO), temperature and pH. Water transparency was tested by using Secchi disc. For laboratory testing, water samples undergo Total Nitrogen (TN), Total Phosphorus (TP), Ammonia Nitrogen, Nitrate and Chlorophyll-a for TSI tests. Data obtained from the testing were analyzed using bathymetry map analysis to determine the sedimentation rate and pattern in Sembrong reservoir for the past years from 1984 to 2013, GRADISTAT for particle size distribution, Carlson's trophic status for TSI and SPSS for the correlation between water and sediment nutrient parameters. Based on the 1984 and 2013 bathymetry maps, the reservoir storage capacity was reduced by 12.54 million m^3 due to sedimentation. This is equal to 0.43% decrease in volume per year. Surface areas of the reservoir undergo shrinkage as much as 1.216 km for 29 years, thus the rate of shrinkage was 41.83 m/year. Estimation of reservoir useful life shows that Sembrong reservoir is still able to operate up to 20 years from 2013 if there is no action taken. From GRADISTAT analysis, particle size distribution in Sembrong reservoir consist of sandy gravel. For the vertical nutrient composition in sediment, the highest composition of total

phosphorus (TP) was obtained at Location 4 in Zone II with 31.41 mg/L at depth of 10 cm from surface while for total nitrogen (TN), the highest composition was also obtained at Location 4 in Zone II with 38.45 mg/L. Sembrong reservoir generally had high nutrient concentrations in the uppermost sediment layers and decreased by sediment depth. The Carlson's trophic status analysis had indicated that Sembrong reservoir was in a eutrophic state with TSI > 50 and graded as bad. For correlation analysis by using SPSS, water and sediment nutrient parameters have a weak relationship with r between 0 – 0.2. As conclusion, preventive action and maintenance should be done to remove the sediment and extend the lifespan of Sembrong reservoir. This analysis gave an insight into the variability of sediment nutrient concentration within the reservoir. It also demonstrates the relationship where water may influence the sediment nutrient in the reservoir.

ABSTRAK

Takungan dari empangan Sembrong merupakan sumber air utama bagi 240,000 orang penduduk di daerah Kluang dan sebahagian Batu Pahat. Kemerosotan kapasiti penyimpanan air yang disebabkan oleh proses pemendapan dan eutrofikasi baru-baru ini sangat berkait rapat dengan isu permasalahan di empangan Sembrong. Justeru itu, bbjektif kajian yang dijalankan ini adalah untuk menganalisis taburan sedimen dan kadar pemendapan di takungan Sembrong dengan menggunakan GIS. Juga, untuk menentukan nutrien-nutrien dan indeks status tropik (TSI) di dalam takungan Sembrong bagi melihat hubungkait di antara parameter nutrient di dalam air dan mendapan. Sebelum menjalankan ujian makmal, proses pensampelan telan dijalankan yang melibatkan pengambilan sampel sedimen dan sampel air. Enam (6) lokasi untuk pensampelan sedimen telah dipilih dan pengorek graviti mudah alih telah digunakan untuk mendapatkan teras sedimen manakala untuk sampel air, tujuh belas (17) lokasi telah dipilih dan sampel diambil menggunakan kaedah cedok. Sebelum menjalankan ujian makmal, teras sedimen telah diproses untuk mengubahnya dari bentuk pepejal ke cecair. Ujian makmal yang dijalankan bagi sampel sedimen terdiri dari Total Nitrogen (TN), Total Phosphorus (TP) dan analisis ayakan untuk menetukan pengedaran saiz zarah. Untuk sampel air pula, ujian in-situ telah dijalankan untuk menguji oksigen terlarut (DO), suhu dan pH. Ketelusan air diuji dengan menggunakan cakera Secchi. Untuk ujian makmal, sampel air menjalani ujian Total Nitrogen (TN), Total Phosphorus (TP), Ammonia Nitrogen, Nitrat dan Chlorophyll-a untuk mendapatkan nilai TSI. Data yang diperoleh daripada ujian makmal kemudiannya akan dianalisis dengan menggunakan analisis peta bathimetri untuk menentukan kadar sedimentasi dan corak taburan mendapan dalam takungan Sembrong untuk tahun-tahun yang lalu dari tahun 1984 hingga 2013, analisis GRADISTAT pula untuk melihat pengedaran saiz zarah, status trofik Carlson digunakan untuk menganalisis TSI dan SPSS untuk mengira hubungan antara parameter nutrient di dalam air dan mendapan. Berdasarkan peta batimetri pada

tahun 1984 dan 2013, kapasiti penyimpanan takungan air berkurangan sebanyak 12.54 juta m3 disebabkan oleh pemendapan. Ianya bersamaan dengan penurunan sebanyak 0.43% setiap tahun. Kawasan pada permukaan takungan mengalami pengecutan sebanyak 1.216 km selama 29 tahun dan mengalami kadar pengecutan sebanyak 41.83 m / tahun. Anggaran hayat bagi takungan menunjukkan bahawa empangan Sembrong masih hanya boleh beroperasi selama 20 tahun lagi dari tahun 2013 sekiranya tiada tindakan pencegahan diambil. Dari analisis GRADISTAT, pengedaran saiz zarah di takungan Sembrong terdiri daripada batu kerikil berpasir. Untuk komposisi nutrien di dalam mendapan, komposisi tertinggi bagi fosforus total (TP) diperolehi di Lokasi 4 yang terletak pada Zon II dengan nilai 31.41 mg / L pada kedalaman 10 cm dari permukaan manakala untuk nitrogen total (TN), komposisi tertinggi juga didapati di Lokasi 4 di Zon II dengan nilai 38.45 mg / L. Empangan Sembrong umumnya mempunyai kepekatan nutrien yang tinggi di lapisan permukaan sedimen dan menurun mengikut kedalaman sedimen. Analisis indek status Carlson pula menunjukkan bahawa takungan Sembrong berada dalam keadaan eutrofik dengan nilai TSI> 50 dan dinilai sebagai buruk. Untuk analisis korelasi dengan menggunakan SPSS, parameter nutrien di dalam air dan sedimen mempunyai hubungan lemah dengan r antara 0 - 0.2. Sebagai kesimpulan, tindakan pencegahan dan penyelenggaraan perlu dilakukan untuk mengurangkan peningkatan sedimen dan memanjangkan jangka hayat takungan Sembrong. Analisis ini memberi gambaran tentang kepelbagaian komposisi nutrien bagi sedimen dalam takungan. Ia juga menunjukkan hubungan di mana nutrien di dalam air di empangan Sembrong boleh mempengaruhi sedimen di dalam takungan.

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LIST OF ABBREVAITIONS

DID	-	Department of Irrigation and Drainage
GIS	-	Geographical Information System
TSI	-	Trophic Status Index
DEM	-	Digital Elevation Method
TIN	-	Triangular Irregular Network

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Lakes and reservoirs are important sources of water supply in Malaysia as they provide multipurpose functions such as hydroelectric power, domestic usage, agriculture, recreation and provide flood protection. However, common problems experienced by lakes and reservoirs all over Malaysia are sedimentation and eutrophication. Most natural rivers are balanced with respect to sediment inflow and outflow. Dam construction dramatically alters this balance since the increased flow depth and decreased flow velocity of a reservoir, reduces the sediment transport capacity and causes settling.

Reservoir sedimentation is a complex process that varies with watershed sediment production, rate of transportation, and mode of deposition. Reservoir sediment depends on the river regime, flood frequencies, reservoir geometry and operation, flocculation potential, sediment consolidation, density currents, and possible land use changes over the life expectancy of the reservoir (Sumi & Hirose, 2009). Sedimentation reduces reservoir storage capacity for flow regulation, water supply, flood control benefits, plus hydropower, navigation, recreation, and environmental benefits that depend on releases from storage. Sediments are an important source of nutrient to freshwater ecosystems. In general, nutrients are introduced into lakes and reservoirs from external sources, such as sewage

discharges, agricultural wastewater, and diffuse runoff from agricultural land (Jeppesen *et al.*, 2007).

Eutrophication caused by excessive inputs of phosphorus (P) and nitrogen (N) has become one of the most common impairments of surface waters that present an ongoing threat to the vitality of freshwater ecosystems, where it often manifests as harmful algal blooms that prevent sunlight from reaching underwater plants and lead to lower oxygen concentrations (Zhu *et al.*, 2013).The contaminants in the sediments could have higher concentrations compared to those found in the surface water. This means that the sediment plays an important role in the nutrients cycle and distribution of contaminants in the ecosystem.

1.2 Problem Statement

Sembrong reservoir is a flood-control reservoir which is managed by Syarikat Air Johor since 1984. The reservoir provides clean water supply to 240,000 consumers in the district of Kluang and some parts of Batu Pahat.

Reservoir storage is often affected by sedimentation due to soil erosion in the catchment area. The rate of reservoir sedimentation depends mainly on the size of a reservoir relative to the amount of sediment flowing into it. As the sediments accumulate, the reservoir gradually loses its ability to store water.

Sediments originated through water erosion act as a potential sink for many hazardous contaminants. Mainly large amounts of nutrients adsorbed to soil particles can be transported via soil erosion to water bodies that result in water pollution problems. The increased concentration of nutrients (nitrogen and phosphorus) in water bodies accelerates the eutrophication process (the growth of algae and other aquatic plants) and it is connected with decreasing of dissolved oxygen levels (Junakova et al., 2013).

Land use changes are seen as the key factor responsible for the changes in sediment and nutrient delivery to downstream water bodies (Harris, 2001).The landuse in Sembrong reservoir has changed extensively with the increment of agricultural activities in 1984 covering 8% to 82% in 2010. Oil palm plantation dominating the land use comprising about 72% of the basin area followed by modern agriculture (19%), commercial and residential (5%), and forest and swamp (4%).

Agricultural activities in the lake basin areas contribute significant sources of pollution especially sediment and nutrients input. Since the catchment of water reservoir is affected predominantly by agricultural production, the main pollution elements in bottom sediment samples are nitrogen and phosphorus (Junakova et al., 2013).

Unplanned farming activities as well as oil palm trees plantation, which covered 87% of the 130 km^2 catchment area in 2015 had caused the Sembrong reservoir to slowly deplete the water reserves due to the eutrophication process or commonly known as 'flooding of algae' (mstar, 2015). The phosphorus and nitrogen concentration in the lake water and estuarine environments, which comes from sediment, is regarded as a major component of the internal source of nutrient. nutrients binding to sediments are the important pollution source because they may cause eutrophication what results in a reduction in the dissolved oxygen content of the water, thus killing off much of the animal and plant life. Such release from sediment may have a significant impact on water quality and may result in continued eutrophication.

According to a recent study conducted by Universiti Teknologi Malaysia (UTM), phosphorus levels in the reservoir had reached 92.28% based on Carlson Trophic Index compared to normal levels of 70% to 80%. Thus, this research is done to determine the effects of sediment composition and distribution on water quality in Sembrong reservoir.

1.3 Objectives

The deposition of sediment is one of the most important problems that affecting the water quality in a reservoir. The main aim of this study is to understand the distribution of sediments and the nature of the sedimentary processes involved in Sembrong reservoir. Thus this study is designed to achieve the following objectives;

1. To analyze the distribution of sediment and sedimentation rate in Sembrong reservoir using GIS.
2. To determine the sediment nutrients in the sediment layer and Trophic Status Index (TSI) in Sembrong Reservoir.

3. To correlate the relationship between water and sediment nutrient parameter.

1.4 Scope of Study

In order to achieve the research objectives, the scopes of this research were divided into three parts. First, the establishment of a GIS database was done for the bathymetry and topography map of Sembrong reservoir. The bathymetry and topography map from previous years (1984 and 2013) were provided by the Department of Irrigation and Drainage (DID), Batu Pahat, Johor. These maps were used to determine the existing area of sediment deposition in the reservoir.

Next, coring and water sampling were conducted at the same locations in the reservoir. Six (6) locations were chosen for sediment sampling and seventeen (17) locations for water sampling. Water samples were taken every month from November 2016 to October 2017 while sediment samples were taken once throughout the year. This is because sediments does not have much signifant changes throughout the year due to the weak flow of water in the reservoir. The sampling process focused along Sembrong reservoir. A portable gravity corer was used to assist the sediment sampling procedure. Sediment samples could provide information regarding sediment depth, particle size and provide samples for laboratory analysis. The limitation of sediment depth analyzed was between 5 and 40 cm. The water samples were collected using grab sampling method. All samples were analyzed to determine the nutrient (Total Nitrogen and Total Phosphorus) concentration in the reservoir.

Nutrient parameters such as total phosphorus and total nitrogen were analyzed from sediment and water samples. Chemical parameters such as ammonia nitrogen, nitrates and chlorophyll-a were tested from water samples to analyze the water quality and trophic status index of the overlying water in Sembrong reservoir. In-situ testing was conducted to obtain the dissolved oxygen, pH, temperature and Secchi depth of water in Sembrong reservoir.

1.5 Significance of Study

This study was carried out to determine the sedimentation rate of distribution in Sembrong reservoir. Sedimentation had occurred since the operation of this reservoir for the last 34 years. Increment of sediment had decreased the lifespan of reservoir and reduced the water-storage capacity due to the high rate of sedimentation.

By carrying out this research, the location of sediment deposited throughout Sembrong reservoir can be identified thus will ease the reservoir management such as dredging. Besides that, this research is conducted to determine the nutrient parameters in the sediment and water. Most of previous researchers only focus on the heavy metals in the sediment contaminants. Less studies were done on nutrient parameters (phosphorus and nitrogen) that leads to the eutrophication in the reservoir.

1.6 Thesis Outline

This thesis is divided into five chapters; Chapter 2 contains the literature review emphasizing the current status of knowledge of the processes related to the reservoir sedimentation. It gives a brief summary of previous works undertaken at various lakes or reservoirs around the world. It also discusses about method, analysis and management of sedimentation process which had been done before.

Chapter 3 highlights the study area, coring methods used and the sampling points. Laboratory techniques for core analysis are described including sample preparation, digestion and analysis of samples. This chapter also covers the research framework, data collection and establishment of GIS data-based for Sembrong Reservoir. Results of GIS application for the study area are presented, analyzed and discussed in Chapter 4. The results focus on qualitative and quantitative evaluation of sedimentation process from the available historical data and the water quality at Sembrong reservoir. Nutrients analysis from water and sediment samples is also disscuss in this chapter. Chapter 5 summarizes the conclusions of this study, suggestions or recommendations for future study

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discusses the characteristics of reservoirs and lakes, sedimentation process, water quality and nutrient input in a reservoir. The main topics discussed in the following section are sedimentation process, water quality and trophic states.

2.2 Characteristic of Reservoir

EPA (2000) characterizes reservoirs as –man-made lakes for which the main purpose of the impoundment is other than recreation (*e.g.*, boating, swimming) or fishing, and the water retention time, water body depth and volume vary widely. Magurran (2013) classified reservoirs as one of the seventy-six lake types based on the origin of the lake formation. He considered the dam as the distinguishing characteristic of reservoirs.

Reservoirs are primarily constructed for flood control, water supply, hydropower generation, or irrigation (Pelicice *et al.,* 2015).They are designed to hold back water and release it in a controlled manner. Depending on the height of the dam and the control of the outgoing flow, water storage can be short (1 day) or long (750+ days) (Walker *et al.,* 2007). When reservoirs are formed from rivers and able to store water, their characteristics are typically intermediate to those rivers and natural lakes. Rreservoirs that are more closely resemble natural lake‘s function

within the ecosystem can be categorized as natural lakes, whereas reservoirs that closely resemble rivers in their physical and chemical characteristics function more like rivers (O'Reilly *et al.,* 2015).

The water quality of reservoir is influenced by the geology of the watershed, climate of the region, and land use within the watershed. Reservoirs receive water input from precipitation, runoff from surrounding land, and groundwater. Unlike lakes, reservoirs receive the major portion of inflow from a few contributing tributaries (Doubek & Carey, 2017). Reservoirs can lose water to the atmosphere from the surface, to the groundwater through seepage from the basin bottom and to downstream receiving waters from the controlled outlet.

Depending on the design of the dam, the outlet can be located near the surface, near the bottom, or somewhere in between. Some dams have multiple depths from which the water can be released. Doubek and Carey (2017) stated that reservoirs that release water from the top more closely resemble natural lakes in this attribute.

2.3 Sedimentation Process

Szmytkiewicz and Zalewska (2014) defined sedimentation as the overall process of particle transport to, emplacement on, removal from and preservation in the reservoir. This definition discerns certain phases/stages of the sedimentation process. The first stage is deposition defined as temporary emplacement from and preservation on the seabed and pertains to this relatively short time of sediment formation. Sediment accumulation is the stage pertaining to a decidedly longer period: it is the result of particle deposition and removal, leading to the preservation of the strata. Particle removal may be due to several mechanisms, e.g. physical erosion, biological re-suspension and chemical dissolution.

In general, reservoirs have larger catchment areas and greater inflows compared to natural lakes. These factors increase the potential for greater sediment (and nutrient) loads to reservoirs. Reservoirs experience longitudinal zones with differing characteristics that influence sedimentation. The riverine zone receives the highest input of particulate matter and is the region where the largest and densest particles settle. Primary production is sometimes limited in this zone because of

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