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Water Quality of Batang Lupar Estuary, Sarawak

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Table of Contents

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

AAS	Atomic Absorption Spectrophotometer
APHA	American Public Health Association
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
DOE	Department of Environment
FTU	Formazin Turbidity Unit
NREB	Natural Resources and Environment Board Sarawak
NTU	Nephelometric Turbidity Units
PPT	Parts Per Thousand
PSU	Practical Salinity Units
TSS	Total Suspended Solid
WQI	Water Quality Index

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ABSTRACT

This study was conducted to determine the water quality status in Batang Lupar estuary of Sarawak. A sampling was carried out at Batang Lupar estuary on 17th December 2012. A total of six sampling stations with 2 km distance between two adjacent stations was chosen. Both in-situ and ex-situ physico-chemical parameters of water were measured and analysed. This included depth (7.40 ± 0.00 m to 10.50 ± 0.00 m), water temperature (29.9 ± 0.05 °C to 31.4 ± 4.35 °C), pH (7.35 ± 0.00 to pH 7.44 ± 0.00), DO (6.29 ± 0.08 mg/L to 8.16 ± 0.23 mg/L), salinity (11.5 ± 0.00 PSU to 18.7 ± 0.00 PSU), conductivity (19.60 ± 0.02 µS to 28.26 ± 0.01 µS), turbidity (87 ± 7.76 FTU to 992 ± 13.85 FTU), water transparency (11 ± 0.00 mm to 24 ± 0.00 mm), chlorophyll-*a* (0.4418 ± 0.00 µg/L to 3.4403 ± 0.30 µg/L), TSS (1358.0 ± 20.29 mg/L to 19348.6 ± 1746.89 mg/L), BOD_5 (1.63 ± 0.12 mg/L to 3.63 ± 0.28 mg/L), Nitrite (0.009 ± 0.00 mg/L to 0.012 ± 0.00 mg/L), Nitrate (0.02 ± 0.00 mg/L to 0.06 ± 0.02 mg/L), Ammonia-Nitrogen (0.32 ± 0.24 mg/L to 2.04 ± 0.12 mg/L), and Orthophosphate (0.03 ± 0.01 mg/L to 0.10 ± 0.09 mg/L). Other than that, heavy metals were analyzed too including As (0.1420 ± 0.09 mg/L to 0.1808 ± 0.03 mg/L), Cu (0.0073 ± 0.00 mg/L to 0.0110 ± 0.00 mg/L), Pb (undetected), Mn (0.0098 ± 0.00 mg/L to 1.1769 ± 0.48 mg/L), Ni (0.0054 ± 0.00 mg/L to 0.0162 ± 0.00 mg/L) and Zn (0.0063 ± 0.00 mg/L to 0.1228 ± 0.04 mg/L). Nitrite, Nitrate, Zn and DO were within the standard range proposed by MWQS of DOE. The water quality of Batang Lupar Estuary was clean and safe. Human residential along the river and other activities such as logging and agriculture are amongst the factor influencing the water quality of Batang Lupar Estuary.

Keywords : Water quality, Batang Lupar, turbidity

ABSTRAK

Kajian ini telah dijalankan untuk menentukan status kualiti air muara Batang Lupar di Sarawak. Kerja lapangan telah dijalankan pada 17 Disember 2012. Sebanyak enam stesen kajian dengan jarak 2 km di antara satu sama lain telah dipilih. Parameter fiziko-kimia in-situ dan ex-situ telah diukur dan di analisa. Ini termasuklah kedalaman (7.40 ± 0.00 m hingga 10.50 ± 0.00 m), suhu air (29.9 ± 0.05 °C hingga 31.4 ± 4.35 °C), pH (7.35 ± 0.00 hingga pH 7.44 ± 0.00), DO (6.29 ± 0.08 mg/L hingga 8.16 ± 0.23 mg/L), kemasinan (11.5 ± 0.00 PSU hingga 18.7 ± 0.00 PSU), konduktiviti (19.60 ± 0.02 µS hingga 28.26 ± 0.01 µS), kekeruhan (87 ± 7.76 FTU hingga 992 ± 13.85 FTU), kejernihan air (11 ± 0.00 mm hingga 24 ± 0.00 mm), klorofil-a (0.4418 ± 0.00 µg/L hingga 3.4403 ± 0.30 µg/L), TSS (1358.0 ± 20.29 mg/L hingga 19348.6 ± 1746.89 mg/L), BOD_5 *(1.63 ± 0.12 mg/L hingga 3.63 ± 0.28 mg/L), Nitrit (0.009 ± 0.00 mg/L hingga 0.012 ± 0.00 mg/L), Nitrat (0.02 ± 0.00 mg/L hingga 0.06 ± 0.02 mg/L), Ammonia-Nitrogen (0.32 ± 0.24 mg/L hingga 2.04 ± 0.12 mg/L), dan Ortofosfat (0.03 ± 0.01 mg/L hingga 0.10 ± 0.09 mg/L). Selain itu, logam berat juga turut dianalisa termasuklah As (0.1420 ± 0.09 mg/L hingga 0.1808 ± 0.03 mg/L), Cu (0.0073 ± 0.00 mg/L hingga 0.0110 ± 0.00 mg/L), Pb (tidak dapat dikesan), Mn (0.0098 ± 0.00 mg/L hingga 1.1769 ± 0.48 mg/L), Ni (0.0054 ± 0.00 mg/L hingga 0.0162 ± 0.00 mg/L) dan Zn (0.0063 ± 0.00 mg/L hingga 0.1228 ± 0.04 mg/L). Nitrit, Nitrat, Zn dan DO berada dalam lingkungan yang ditetapkan MWQS oleh DOE. Kualiti air muara Batang Lupar adalah bersih dan selamat. Penempatan penduduk di sepanjang sungai dan aktiviti lain seperti pembalakan, dan pertanian adalah antara faktor yang mempengaruhi kualiti air muara Batang Lupar.*

Kata kunci : Kualiti air, Batang Lupar, kekeruhan

1.0 Introduction

1.1 Research Background

Water is an astoundingly remarkable chemical compound of utterly imperative environmental importance that it is frequently described as 'the universal solvent' or 'the liquid of life' (Thanapalasingam, 2005). Correspondingly, water's presence in the biota acts as the fulcrum of biochemical metabolism due to its unique physical and chemical properties (Jalim, 2008). It is currently estimated that approximately 71% of the earth is covered with 1,370 million km^3 volume of water (Ariffin, 2011), and that, this consists of the oceans and seas, the ice and snow of the polar regions and even water contained in surface soils and underground strata, lakes and rivers. In addition, water is one vital reservoir for nutrients and other biologically fundamental materials' storage, apart from being one significant medium for materials transport between biotic and abiotic ecosystems (Thanapalasingam, 2005).

Clean water from an unpolluted source is imperative as to supply water for various purposes for daily usage, consumption, food production and electricity generation. Nevertheless, inevitable natural processes such as precipitation inputs, erosion, weathering of crust materials, over and above the anthropogenic influences, urban, industrial and agricultural activities calls for an ever increasing exploitation of water resources (Prasanna & Ranjan, 2010). Accordingly, pollution control, water supply and effective sewerage system within a particular country are parts of closely knitted elements of water resources management and therefore an organized management is significant (Muyibi *et al*., 2007).

Malaysia is one of those countries which is highly dependent upon rivers as source of living that generally, development of this country is immensely contributed by the rivers through activities such as power generation, water for agricultural or fisheries activities, industrial consumption besides as means of transportation, recreation and communication for the locals. Through history, the development of towns and cities in Malaysia too began from the settlements along rivers and estuaries due to variety of benefits obtained. With the advent of civilizations and accelerating human population expansion, the ranges of requirement of water have increased in demand together with higher water quality.

However, the rivers in Sarawak nowadays, which have been persistently put under escalating stress due to rapid and swift population growth, together with land development along river basin, urbanization and industrialization, are now generally facing environmental deterioration and severe water pollution. The most frequent water quality parameters measured are those related to water pollution due to anthropogenic factors, as such, land clearing, sewage discharge and industrial effluents. In Sarawak, the responsibilities of monitoring water quality are done by the Department of Environment (DOE) and Natural Resource and Environmental Board (NREB) (Latip, 2005). As a matter of fact, the total number of river basins monitored by 2008 was 143, and that, the number of stations found to be clean was 1,063 (58%), followed by slightly polluted 412 (38%), and last but not least, 3 (4%) polluted (Ahmad, 2010).

According to Environmental Quality Act 1974 (Act 127), pollution is defined as "any direct or indirect alteration of the physical, thermal, chemical, or biological properties of any part of the environment by discharging, emitting, or depositing environmentally hazardous substances, pollutants or wastes so as to affect any beneficial use adversely, to cause a condition which is hazardous or potentially hazardous to public health, safety, or welfare..".

Frequently, contaminants that are almost certainly present in source water are microbial contaminants such as virus and bacteria, or inorganic contaminants such as salts and metals, pesticides and herbicides (Ahmad, 2010). As according to study conducted by Khalit (2010), recurrent pollutants in Malaysia are of domestic sewage, waste from livestock and farms, run-offs from towns, riverside squatters and mining waste. These pollutants will inevitably cause water pollution to the rivers and subsequently be flowed together to the estuarine environment in a much magnified concentration. For example, Sungai Juru of Seberang Perai, Pulau Pinang was classified as the most polluted river in Malaysia by Department of Environment (DOE), in which, the Water Quality Index (WQI) is 5 portraying it is highly polluted and the survival of marine organism is very low (Nordin, 2009).

Although the fact that the quality of Malaysia's environment with respect to river, marine and ground water is currently within conventional discrepancies, various efforts are still intensified in promoting sustainable natural resources management (Khalit, 2010). In Sarawak itself, it was proposed by the Natural Resources and Environment Board (NREB), in order to reduce water pollution and improve water quality, a river adoption programme will be introduced. According to NREB controller, this plan would introduce setting up solid waste traps in drains, installing septic tanks for village houses with hanging toilets over rivers and carrying out river cleaning programmes (The Star Online, 2008). In addition, in the Eighth Malaysia Plan, Ministry of Natural Sources and Environment has allocated a total of RM250 million budget for cleaning and replenishing the rivers projects (Nordin, 2009).

Apart from pollution, heavy metal contamination in water system too is one of the biggest concerns in Malaysia as the country moves towards the realization of vision 2020. Heavy metals can be toxic if available higher than the minimum requirements, albeit some of them are fundamentally required as micronutrients (Ahmad *et al.*, 2009). Sources of heavy metals are for instance land surface run-off, rainfall precipitation and factory waste outlet point discharge. In fact, some industries in Malaysia were reported to be operating either without effluent treatment system (ETP) or with inefficient ETP and that, these industries had complications in complying with parameters such as nickel, copper, lead, and zinc (Thanapalasingam, 2005).

The study site of Batang Lupar estuary is one of the well-known rivers in Sarawak, inhabited by locals and that, most rural villagers in Lingga still depend on Batang Lupar and tributaries to supplement for their livelihoods (Borneo Post Online, 2011). Batang Lupar estuary is one vigorous estuarine environment which is characterized by its fast flowing stream and the fact that it is a mangrove ecosystem; the estuarine environment incorporates the coastal tidal swamps and copious streams in which evidently playing major role in the sustenance of the coastal marine fisheries. It was reported that, continuous land clearing has exposed the land and drainage alterations may cause further erosion and sediment run-off into nearby streams during heavy downfall (Rajali & Gambang, 2000). The sediment run-off would likely intensify the concentration of both particulate organic and inorganic material, in which either way would be introduced to or resuspended in the environment instigating an elevated organic enrichment. Consequently, this organic load would put high demand on the concentration of the Dissolved Oxygen (DO), ergo, leading to high Biochemical Oxygen

Demand (BOD), and this abrupt decrease of Dissolved Oxygen concentration will kill the marine organisms such as fishes and even plankton community.

1.2 Objectives

The main aims of this research are:

i. To determine the physico-chemical parameters of the water in Batang Lupar estuary

ii. To determine the status of water quality in Batang Lupar estuary

iii. To establish a baseline data for water quality in Batang Lupar estuary

2.0 Literature Review

2.1 Water Quality

Water quality is a term used to articulate the sustainability of the water to remain for various practices and is determined by measuring and comparing to a standard list of physico-chemical characteristics, besides is quantitative and can be measured accurately without ambiguity (Jalim, 2008). Water quality too, is considered as the uppermost factor in influencing health and state of diseases in both man and animals (Ariffin, 2011). Any specified parameter which is out of tolerance range could be considered as being detrimental to the living organisms (Yap *et al.*, 2011).

The primary rationale to water quality study is to sustain and protect designated uses of water, for instance, human consumption, livestock watering, irrigation, fisheries and agricultural purposes, recreation; while maintaining and supporting aquatic life and functioning for aquatic ecosystems (Nordin, 2009). Even though water quality monitoring does not measure one particular ecosystem's environmental health, it is debated that, the water quality of an aquatic ecosystem can supply rapid assessment of the environmental quality before it is manifested in living organisms (Yap *et al.*, 2011). Therefore, it is one vital requirement for appropriate water quality monitoring for future planning and management of clean water resources (Ghumman, 2011).

Water quality parameters commonly measured are those related to water pollution due to land clearing, agricultural wastes, sewage discharge from the residential areas nearby and industrial effluents. For instance, in the coast of Kedah, Perak and Negeri Sembilan, pollution by silt was the worst. Whereas, oil and grease pollution were mostly seen in Terengganu, Pahang and Negeri Sembilan. Lead contamination, on the other hand, was evident in Terengganu, Kelantan and Perak (Khalit, 2010).

But besides the notorious anthropogenic pollutions, there are also pollutants that come naturally by the action of water and wind streams that are affecting the water. For example, the constantly increasing amounts of sedimentation can be expected due to the deterioration of the land environment through human exploitation of forests. Based on these data (physical, chemical and biological parameters), water quality is determined by comparing with relevant and at the same time standardized standards. As such, in an estuarine environment, water quality can be very much influenced by torrential rains, which is common in the tropics that this will add significantly to the water body as sheet-flow (Ong *et al.*, 1991).

In general, water quality in a region is principally determined by both natural processes (weathering and soil erosion) and by anthropogenic inputs (municipal and industrial wastewater discharge) (Ariffin, 2011). The municipal and industrial effluents signifies the constant polluting source, whereas, surface run-off is one seasonal phenomenon, primarily affected by climate.

In Malaysia, water pollution is recurrently caused by point and non-point sources. Point sources encompass sewage treatment plants, manufacturing and agro-based industries as well as animal farms. On the other hand, non-point sources are made up of diffused sources such as agricultural activities and surface run-offs (Khalit, 2010).

Generally in Sarawak itself, several continuously developing human activities that have directly and indirectly degraded the natural environment, particularly in regard to estuarine water quality includes those of clearing of forests and natural vegetation for agriculture activities, timber harvesting, excessive use of fertilizers and pesticide with the development of agriculture plantations in peat swamp forest, and also urban developments such as housing, commercial and industrial complexes. Apart from that, infrastructure development such as road construction, besides discharging of untreated waste water and raw sewage, together with disposal of the city effluent into which the majority of the drain discharge their mixture of effluent and storm water.

Subsequently, it has been discovered that, the importance of implementation of establishing baselines and detecting changes in river water quality, soon prompted the Department of Environment (DOE) to immediately begin its monitoring programme in 1978 (Malaysia environmental Quality Report, 2004). This is one practical implementation of forward-looking precaution in line with Government's effort to control development activities, especially in the upstream areas as to decrease the number of pollution cases. According to Sumok (2001) a River Water Quality Monitoring programme has been started by Natural Resources and Environment Board Sarawak (NREB) since 1998. In conjunction with this, the Water Quality Index (WQI) was introduced and that WQI integrates complex data to generate a score that describes the status of water quality to the public as well as decision and policy makers (Bordalo *et al*., 2001). The WQI is a unitless number between 0 and 100 with the higher value indicating better quality of water. The Water Quality Index (WQI) generally used to appraise river water quality consists of various parameters such as Dissolved Oxygen

(DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammoniacal Nitrogen (NH_3N), Suspended Solids (SS), pH, conductivity, turbidity, salinity and temperature (Malaysia environmental Quality Report, 2004). But however, for estuarine water quality, Water Quality Index (WQI) is inapplicable due to the fact that it is used for freshwater only. As for estuarine waters, Malaysia Marine Water Quality Criteria and Standard by Department of Environment (Department of Environment, 2010) will be used whereby comparison with baseline data will be done.

Apart from that, the existence of National Monitoring Network which was originally established in 1978, with their aims of establishing the status of river water quality and detecting changes in water quality as a result of development activities, recently established 902 manual stations in 120 basins in Malaysia. Out of these 926 monitoring stations, 540 (58%) were found to be clean, 278 (30%) slightly polluted and 108 (12%) polluted (Rahman, 2001).

In Sarawak, besides NREB, many other Federal agencies, such as, the Department of Environment (DOE), Health Department and the local councils, as well as, the private sectors, including universities and consultants also conduct water quality studies. The data collected are for their own use and for specific purposes. Meanwhile, data collected by State, Federal agencies and private entities are needed for the assessment we need for making better pollution control decisions. These raw data will be used in order to determine the waters quality standards (Sumok, 2001).

Therefore, considering that water is becoming progressively inadequate or insufficient, monitoring water quality of rivers is a subject of ongoing concern and research (Massoud, 2011). It is imperative and crucial to prevent and control water pollution, while having reliable management and mitigation measures as to enhance water quality as a whole.

2.2 Estuarine Characteristics

Estuarine; which is a vital component of complex and dynamic coastal watersheds can be best defined as a passage, as the mouth of a river or lake where the tide meets the river current; more commonly, an arm of the sea at the lower end of a river; a firth (Shabdin, 2011).

An estuary is an inlet of the sea which reaches a river valley as far as the upper limit of tidal rise, frequently being divisible into three primary sectors; a marine or lower estuary, in free connection with the open sea; a middle estuary subject to strong salt and freshwater mixing; and an upper or fluvial estuary, characterized by freshwater but subject to daily tidal action.

Commonly characterized by a partially enclosed body of water whereby two different water bodies meet and mix, an estuary usually mixes freshwater from river or streams with salt water from the ocean that this will therefore form brackish water. Brackish environments contain diluted sea water which enters through tidal rivers or percolation through permeable deposits that lie between the basin and sea coast (Jalim, 2008). Brackish water is acknowledged for being slow, muddy, sluggish and attractive but of high fertility, and it leads to the formation of mangrove area dominated by *Rhizophora* spp, *Avicennia* spp and *Nipah* spp (Latip, 2005).

Water quality in estuaries generally fluctuates naturally because of the dynamic mixing of fresh and salt water. Apart from that, the mixing zone for freshwater and seawater within the estuary can be outstandingly convoluted, affected by the volume and rate of discharge of fresh water from the river, the amount and grain size of sediments in the river, the topography of the coastline and the tidal range (Natmancom, 1986).

The physical water quality parameters within an estuary are dependent upon the structures of the estuary itself and also the location being observed. For instance, locations in inlets and open bays may see a tidal effect, as water moves in and out during the daily tidal cycle. In addition, the concentration of nitrogen of estuary also tend to increase in the dry season during periods of relatively light feeding because freshwater input is insignificant and exchange with bay water is low (Teichert-Coddington *et al.*, 1996).

The site of study, Batang Lupar estuary, is considered as one of the most important estuaries in Sarawak apart from Batang Rajang (Latip, 2005). The notorious Batang Lupar is highly famed for the native legendary men-eating crocodiles infesting the river itself besides the annually occurring tidal bore (*benak*) rushing up the Batang Lupar which became a famous tourist attraction. Apart from that, Batang Lupar estuary is also one of the estuaries whereby endemic species, Terubok fish (*Tenualosa toli*) can be found besides Batang Saribas and Batang Lasa, all of Sarawak (Tumiran *et al.*, 2011). A study indicated that, Batang Lupar estuary is used as a nursery ground by juveniles clupeids such as Terubok fish (*Tenualosa toli*) (Rajali & Gambang, 2000). Another study also shows that Batang Lupar estuary is famed for the harboring of Yellow Pufferfish (*Xenopterus naritus*) that this species is abundant only in Sarawak (Gambang & Pek Hiok, 2004).

In addition, Batang Lupar estuary was a mangrove-estuary which was located at the south-western part of Sarawak that was mostly inhabited by rural villagers due to the importance of the river itself to supplement for their livelihoods. The locals of Batang Lupar are mostly traditional fishermen, employing gears like drift nets, stake net and bag nets due to the high turbidity and fast flowing waters. The area of fishing is confined within the estuarine waters from Pulau Burong to as far as Pulau Seduku (Rajali & Gambang, 2000). Recent study indicated that extensive logging activities up the Batang Lupar river basin has led to serious erosion and leading to heavy siltation around Pulau Burong area (Rajali & Gambang, 2000). This will as a result, imperceptibly affect the water quality parameter themselves and furthermore, they will fluctuate easily due to the location of the estuary which constantly receives high frequency of high and low tide that the salinity, temperature, Dissolved Oxygen content and many other physico-chemical parameters will be affected. Ecological studies in Batang Lupar estuaries have shown that large quantity of energy, in the form of plant detritus are exported from mangrove swamps into the coastal zone (Rajali & Gambang, 2000).

Batang Lupar estuary is a well-known estuary which is classified as mangrove-estuary, and therefore, the characteristics of it are mangrove based. The mangrove ecosystem, which encompasses the coastal tidal swamps and the copious streams that flow through it has been widely acknowledged to play an imperative role in the sustenance of the coastal marine fisheries (Rajali & Gambang, 2000). Batang Lupar's mangrove estuary is characterized by brackish water due to the mixing of two water bodies, namely freshwater and seawater, and that they have an assortment of purposes such as ecological, socioeconomic and also physical that are all significant components for the stability of biodiversity, coastal lines and communities living in the surrounding.

Mangrove estuarine ecosystems are classified as one of the highly productive tropical ecosystems and, they are ecologically sensitive besides providing physical protection for the communities. Mangroves are open systems that they are significant in providing energy and matter to estuarine and coastal systems via leaves litter fall and decomposition (Jalim, 2008). More significantly, they are believed to play a major role in supporting tropical estuarine and coastal food webs (Tripathy, 2005). It serves as one multi-functional ecosystem that many species inhabiting the shallow water zone of the continental shelf use the estuary as a nursery ground prior to migrating to the open sea (Rajali & Gambang, 2000). Additional unique features and exceptional adaptations like breathing roots, buttress and above-ground roots allow them to live and survive in the anaerobic condition and salty water present (Gandaseca *et al.,* 2011).

The hydrodynamics and hypsometry of a mangrove estuary is complex that at low tide, the water is confined to the main channel but once the tide rises, unvegetated tidal flats are inundated, then the estuary's banks will be overflowed progressively. Only during rare extreme high spring tides is the entire area of mangrove vegetation flooded (Ong *et al.,* 1991). The fact that estuarine environment is one complex blend of constantly changing habitat distinguishes itself from freshwater rivers and lakes. Streams, rivers and lakes' water quality are prone to fluctuate homogenously within a well-defined range mainly due to effects by rainfall and seasons. Estuary, in contrast, the parameters alter abruptly in time and space, and