Faculty of Resource Science and Technology

WATER AND SEDIMENT QUALITY OF MURUM RESERVOIR, INUNDATED PLIERAN RIVER AND DANUM RIVER

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Water and Sediment Quality of Murum Reservoir, Inundated Plieran River and Danum River

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Declaration

I hereby declare that this thesis entitled ‘Water and Sediment Quality of Murum Reservoir, Inundated Plieran River and Danum River’ is an original research work of my own excluded for the references document. The report has not been accepted for any degree and is not concurrently submitted for any other degree.

(TOH YU MEI)

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List of Abbreviations

%	Percent
˚C	Degrees Celcius
AN	Ammoniacal Nitrogen
BOD_5	Five-day Biochemical Oxygen Demand
Chl-a	Chlorophyll-*a*
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
EC	Electrical Conductivity
g	gram
H_2O_2	Hydrogen Peroxide
H_2SO_4	Sulfuric acid
km^2	kilometer square
L	Litre
m	meter
m^3	meter cube
µg	microgram
µm	micrometer
µS/cm	micro Siemens per centimeter
mg	milligram
mg/L	milligram per Litre
mg/m^3	milligram per meter cube
mL	milliLiter

mL/L	milliLiter per Litre
mm	millimeter
nm	nanometer
NO_2-N	Nitrite-Nitrogen
NO_3-N	Nitrate-Nitrogen
NTU	Nephelometric Turbidity Unit
NWQS	National Water Quality Standards of Malaysia
pH	Negative Logarithm of Hydrogen Ion Activity
PO_4-P	Soluble Reactive Phosphorus
PSA	Particle Size Analysis
rpm	round per minute
SRP	Soluble Reactive Phosphorus
TAN	Total Ammonia Nitrogen
TN	Total Nitrogen
TOC	Total Organic Carbon
TP	Total Phosphorus
TS^{2-}	Total Sulfide
TSI	Trophic State Index
TSS	Total Suspended Solids
Vol	Volume
WQI	Water Quality Index

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ABSTRACT

Dam construction could lead to environmental problems. Three stations, inundated Pleiran River (S1), inundated Danum River (S2) and Murum reservoir (S3) were selected to determine the water quality at 3 depths and sediment quality. Samples collection were in July 2014 and February 2015. S1 which was near to the submerged vegetation area showed the highest BOD_5 (6.77 mg/L), the highest COD (122.03 mg/L) and the highest chl-*a* (12.13 mg/m^3) at subsurface in July 2014. S1 had the highest turbidity (50.70 NTU), the highest TAN (0.791 mg/L), the highest SRP (39.09 µg/L) and the highest TS^{2-} (0.09 mg/L) at 20 m depth in February 2015. Total sulfide in both trips showed similar trend at 3 depths. Both sediment texture in S1 and S3 were sandy clay loam; S2 was clay. TSI showed all stations were eutrophic. S2 and S3 at subsurface in July 2014 and S1 and S3 at subsurface in February 2015 showed WQI of Class II (76.5 – 92.7). Other stations fall in Class III (51.9 – 76.5) and IV (31.0 – 51.9) which could affect the healthy growth of aquatic life. Therefore, it is recommended to pre-clear vegetation before the impoundment of the river.

Key words: Murum Dam, water quality, partially-filled, sediment, WQI

ABSTRAK

Pembinaan empangan akan menyebabkan masalah alam sekitar. Tiga stesen, Sungai Pleiran dibanjiri (S1), Sungai Danum dibanjiri (S2) dan takungan Murum (S3) telah dipilih untuk menyelidik kualiti air dalam 3 kedalaman serta kualiti sedimen. Pengambilan sampel pada Julai 2014 dan Februari 2015. S1 yang berhampiran dengan kawasan pokok tenggelam menunjukkan BOD_5 tertinggi (6.77 mg/L), COD tertinggi (122.03 mg/L) dan chl-a tertinggi (12.13 mg/m^3) di permukaan pada Julai 2014. S1 mempunyai kekeruhan tertinggi (50.70 NTU), TAN tertinggi (0.791 mg/L), SRP tertinggi (39.09 µg/L) dan TS^{2-} tertinggi (0.09 mg/L) dalam kedalaman 20 m pada Februari 2015. Total sulfide dalam kedua-dua perjalanan menunjukkan trend yang serupa dalam 3 kedalaman. Tekstur sedimen di S1 dan S3 adalah berpasir tanah liat gembur; S2 adalah tanah liat. TSI menunjukkan semua stesen termasuk dalam eutrofik. S2 dan S3 di permukaan pada Julai 2014 serta S1 dan S3 di permukaan pada Februari 2015 menunjukkan WQI Kelas II (76.5 – 92.7). Stesen lain termasuk dalam Kelas III (51.9 – 76.5) dan IV (31.0 – 51.9) mempengaruhi pertumbuhan sihat kehidupan akuatik. Oleh itu, disyorkan untuk menebang pokok sebelum menaikkan paras air di sungai.

***Kata kunci**: Empangan Murum, kualiti air, sebahagiannya berisi, sedimen, WQI*

1.0 Introduction

Water and sediment quality play an important role in river and reservoir. Dam and reservoir are built for drinking water, hydroelectric generation, flood control, agriculture water supply and recreation (Braga *et al*., 1998; Verghese, 2001; Vyas, 2001). Dam construction has caused some common environmental problems which are degradation of water quality, severe bio-contamination with bacteria, sediment deposition in reservoir and loss of aquatic life (Eisakhani & Malakahmad, 2009; Gasim *et al*., 2006). A study by Hu *et al*. (2009) showed that construction of Three Gorges Dam on Yangtze River in China has affected the continuity of the river system for transportation of sediment to downstream of the river. Dam construction in Tasik Chini, Malaysia, showed the water movement becomes less dynamic and affected the fish activities in that area (Gasim *et al*., 2006).

Dry and wet season and anthropogenic factors contributed to the water and sediment quality. Raining during wet season has caused soil erosion into river and increased the turbidity and total suspended particles in the river (Gasim *et al*., 2006). Human activities such as logging, agricultural activities, mining, wastewater discharge from residential area are affected the water and sediment quality (Eisakhani & Malakahmad, 2009; Gasim *et al*., 2006). Marchand *et al.* (2012) reported the water discharge from residential area into Roodeplaat Dam (RD) in city Pretoria, South Africa has affected the aquatic life and people who rely on the water resource. Runoffs of pesticides, herbicides and fertilizers used in agricultural activities have increased the concentration of total nitrate and total phosphorus in the river and led to eutrophication process (Eisakhani & Malakahmad, 2009). Sediment analysis is important as the contaminants are bound to suspended particles and settled with sediments (Mossop *et al*., 2013).

The construction of Murum dam started in the year 2008 and was expected to operate in the year 2014 (Sovacool & Bulan, 2011; Wong, 2014). As stated by Sarawak Energy (2013), Murum dam which is located in Belaga, Sarawak has a reservoir height of 141 m, catchment area of 2750 km^2 and it is located upstream of Bakun dam. The main purpose of Murum dam is to generate 944MW of electricity. All the energy generated from Murum dam and Bakun dam was supplied to phosphate, polycrystalline silicon, manganese and aluminium industries (Wong, 2014). People still carry out fishing and hunting activities within the inundated Plieran River, inundated Danum River and reservoir. In addition, logging and conversion of forest to palm oil plantations around the Murum dam catchment area which covered more than 100,000 hectares of land and forest areas may affect the water and sediment quality of Murum reservoir and river (Chidambar, 2014). It is important to carry out water and sediment analysis in Murum dam where literature on the water and sediment quality of this reservoir and river is limited. Therefore, the objective of this study was to determine the water quality of the Murum reservoir and river at different depths of the partially-filled and fully-filled reservoir as well as sediment quality nearby the sampling stations. The water quality was classified according to Water Quality Index (WQI) and Trophic State Index (TSI).

2.0 Literature review

2.1 Water Quality Parameters

2.1.1 Temperature

Temperature plays an important role in a river. Fluctuation of water temperature will affect the photosynthesis rate of plant, physiological responses, metabolic rate and life cycle of aquatic life (Poole & Berman, 2001; McCaffrey, n.d.). McCaffrey (n.d.) stated the temperature change has affected the aquatic life as different organisms have different optimum temperature for them to survive. Temperature is related to dissolved oxygen and depth. Badran (2001) mentioned the higher the water temperature, the lower the amount of dissolved oxygen. Temperature increases as depth decreases (*Understanding Water Temperature*, n.d.). Water surface gains heat energy directly from sunlight (*Understanding Water Temperature*, n.d.). Water temperature is raised due to the suspended solids which tend to absorb heat from sunlight (Kumar *et al*., 2010). In reservoir, thermal stratification happens due to the change in water density with temperature (Chowdhury *et al*., 2014). Ling *et al*. (2013b) reported thermocline occurs between 7-11 m in Batang Ai Reservoir. Thermocline layer in reservoir inhibits the oxygen to mix from epilimnion layer to hypolimnion layer (Baharim *et al*., 2011). Thermal stratification also reduces the DO level and stimulates algae bloom (Chowdhury *et al*., 2014).

2.1.2 pH

Kwok (2011) stated that pH is used to measure the acidity and alkalinity of water. Presence of more hydrogen ions than hydroxide ions has caused acidity with pH less than 7 in water whereas alkalinity with pH more than 7 happens when the presence of more hydroxide ion than hydrogen ions. pH of most natural waters is between 6.0 – 8.5 (Chapman, 1996). Blood pH of fish and other organisms have average value of 7.4. Therefore, fish can adapt itself to the external environment and internal body environment. Any change in pH in the river will cause the death of fish (Kwok, 2011). According to Ling *et al*. (2010), the increase of nutrients have induced the formation of algae bloom and lead to increase the pH value. Photosynthesis of algae produced oxygen and increased number of hydroxide ion (Gerardi, 2015). Low value of pH is due to decomposition of organic matter by bacteria in sediment (Nyanti *et al*., 2012a).

2.1.3 Dissolved Oxygen (DO)

Dissolved oxygen is the concentration of oxygen gas dissolved in water. According to Lawson (1995), 5 mg/L of DO is needed for the healthy growth of aquatic life. Ohio EPA (2014) stated anoxic condition is fall below 0.5 mg/L. Dissolved oxygen is affected by water turbulence, temperature, suspended solid and organic matter. The DO level increases as the water turbulence increases. More oxygen is introduced into the river (Kwok, 2011). Nyanti *et al*. (2012c) reported high DO level in Kebhor River of Bakun hydroelectric reservoir is due to the water turbulence. Badran (2001) mentioned the higher the water temperature, the lower the amount of dissolved oxygen. According to Chapman (1996), thermal stratification caused the decrease of oxygen level in hypolimnion layer. Increase in suspended solids cause the decrease of DO level in water. Suspended solids tend to trap heat and make oxygen less soluble in water (*Understanding Dissolved Oxygen*, n.d.). Yisa and Jimoh (2010) mentioned that low DO value is due to organic matter and nutrient runoff from industries. Enriched nutrient in water caused algae blooms. According to *Understanding Dissolved Oxygen* (n.d.), algae blooms used up oxygen and affect the aquatic lives which require oxygen to live. Decomposition of algae bloom by bacteria leads to depletion of DO in water. This caused the death of aquatic lives. Besides, Chapman (1996) mentioned that decomposition of submerged vegetation during reservoir impoundment reduced the DO level.

2.1.4 Electrical conductivity (EC)

Electrical conductivity should remain below 1000 – 1500 μS/cm to maintain the aquatic ecosystem (Kwok, 2011). EC is the ability of water to conduct electrical current. EC is affected by the total dissolved solids which are sodium ion, potassium ion, magnesium ion, chloride ion, sulphate ion and carbonate ion. Increase of total dissolved solids are due to the wastewater discharge, fertilizer runoff and flow of water through rock or soil (Das *et al*., 2006). Hossain *et al*. (2013) mentioned the high rainfall during wet season increased the total dissolved solid. According to Das *et al*. (2006), EC increases with water temperature. Higher water temperature dissolved more mineral from rocks into water (Das *et al*., 2006). As stated by Chang and Wen (1997), newly impoundment of water in reservoir shows low EC. This is due to the low mineral loads in soil, rock and submerged vegetation in the flooded area.

2.1.5 Turbidity

Kwok (2011) mentioned turbidity is the measured of cloudiness of water due to the total suspended solids in water. Turbidity is measured in nephelometric turbidity unit (NTU). Chapman (1996) stated the high turbidity represents absorption of light by suspended particles in water. High suspended solids in water are due to soil and silt surface runoff, algae growth, heavy rainfall and pollution with organic matter (Chapman, 1996; Kwok, 2011; Nyanti *et al*., 2012c). High turbidity in the water inhibits the penetration of sunlight into water. Low rate of photosynthesis by phytoplankton has affected the aquatic life by reduced the dissolved oxygen and food in the water. Suspended solids can clog the gill function of fish and inhibit the development of fish eggs (Minnesota Pollution Control Agency, 2008).

2.1.6 Transparency

Kentucky River Basin Assessment Report (n.d.) stated that the transparency of water is the amount of penetration of sunlight into the water. Transparency of water decreased due to the presence of suspended particles from heavy rainfall, flooding and nutrient runoff. According to Fuller *et al.* (2011), transparency is reduced by the quantity of algae of phytoplankton in the water, tannic acid and turbidity.

2.1.7 Five-day Biochemical Oxygen Demand (BOD_5)

According to Yang *et al*. (2009), biochemical oxygen demand is the amount of oxygen used in the oxidation of organic and inorganic compounds by microorganism. Mean BOD_5 value for unpolluted water is 2 mg/L and 3.0 – 6.0 mg/L for aquatic life of European Union standard (Chapman, 1996). BOD_5 value for unpolluted water is 1 mg/L for National Water Quality Standards for Malaysia (DOE, 2012). From previous studies, higher BOD_5 value is due to the untreated wastewater from residential area (Ling *et al*., 2009; Ling *et al*., 2013b). Nutrients runoff stimulates algae bloom in the water body. The death of algae contributes to the organic matter and decomposed by bacteria in the water. As a result, oxygen is consumed by bacteria and BOD level increases. Aquatic life is threatened due to the low DO level in the water (*Biological Oxygen Demand – Overview*, n.d.).

2.1.8 Total Suspended Solids (TSS)

Total suspended solids are the concentration of suspended particles in water (Queenan *et al*., 1996). Kumar *et al*. (2010) stated the suspended solids tend to absorb heat from sunlight and increased the water temperature. High suspended solids in water are due to soil and silt surface runoff, algae growth, heavy rainfall and pollution with organic matter (Chapman, 1996; Kwok, 2011; Nyanti *et al*., 2012c). Ling *et al*. (2010) reported high level of total suspended solids at Santubong River due to the new road development and construction in progress. Total suspended solids have affected the DO and BOD_5 level in the water (Nyanti *et al*., 2012a).

2.1.9 Nitrite-Nitrogen (NO_2-N) and Nitrate-Nitrogen (NO_3-N)

Camargo and Ward (1992) mentioned NO_3-N is the stable form of nitrogen whereas NO_2-N contains nitrogen with unstable oxidation state and NO_2-N is easily being oxidized into NO_3-N. NO_2-N is more toxic than NO_3-N. NO_3-N is least toxic but it occupies high concentration in water. Extensive used of fertilizers in fish farming and effluent from wastewater treatment plants contribute high level of NO_2-N and NO_3-N (Boyd, 2003; Gasim *et al*., 2006). U.S. Environmental Protection Agency (2007) stated NO_2-N and NO_3-N which are soluble in water and move into river through leaching or runoff. Elevated nutrient level causes eutrophication process in the river and affects the aquatic life. Studies show the nutrients runoff into groundwater have affected drinking water source. Methemoglobinemia or known as blue baby syndrome occurs in infants who drink the contaminated water (U.S. Environmental Protection Agency, 1991).