Faculty of Resource Science and Technology

Water and Sediment Quality of Rajang River at Pelagus Area, Sarawak

Phan Tze Pei (38390)

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Declaration

I, **Phan Tze Pei, 38390**, from **FACULTY OF RESOURCE SCIENCE AND TECHNOLOGY** hereby declare that the work entitled. "**WATER AND SEDIMENT QUALITY OF RAJANG RIVER AT PELAGUS AREA, SARAWAK"** is my original work. I have not copied from any other students' work or from any other sources except where due reference or acknowledgement is made explicitly in the text, nor has any part been written for me by another person.

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Tables of Contents

List of Abbreviations

DO = Dissolved oxygen

EC = Electrical conductivity

TSS = Total suspended solids

NO_3^- -N = Nitrate

NO_2^- -N = Nitrite

TAN = Total ammonia nitrogen

Org-N = Total Organic nitrogen

TN = Total nitrogen

SRP / PO_4^{2-}-P= Soluble reactive phosphate

TP = Total phosphorus

TS^{2-} = Total Sulphide

COD = Chemical oxygen demand

BOD = Biochemical oxygen demand

WC = Water content

LOI / OM = Organic content

TOC = Total organic carbon

List of Figures and Tables

Water and Sediment Quality of Rajang River at Pelagus Area, Sarawak

Phan Tze Pei
Resource Chemistry**,** Faculty of Resource Science and Technology, Universiti Malaysia Sarawak

ABSTRACT

This study was carried out to examine the water and sediment quality of Rajang River at Pelagus area to produce a baseline reference of the environment before the construction of a hydroelectric power dam that has been scheduled in the development plan of Sarawak. Samples were collected at 12 stations along the Rajang River from Pelagus Rapid to Punan Bah on 27th to 28th August 2014 and 14th to 15th January 2015. Results of this study show that water quality was affected by logging, vegetation and waste from households and animals around the study area. The total suspended solids and turbidity of stations 1, 5, 6, 7, 10, 11 and 12 exceeded Class II limit of 50 mg/L while dissolved oxygen of stations 1, 6 and 11 fall into Class III (3 – 5 mg/L) based on INWQS. Biochemical oxygen demand of stations 1, 2, 4, 5, 6, 7, 8, 9, 10, 11 and 12 are not complied with Class II (1 – 3 mg/L) while chemical oxygen demand of all the stations are exceeded Class II limit 25 mg/L based on INWQS. Moreover, total ammonia nitrogen of all the stations except station 8 exceeded Class II limit of 0.3 mg/L According WQI, only stations 2, 3, and 4 which are tributaries are classified under Class II (76.5 – 92.7) while stations 1, 6, 7 and 11 that are located at main river and other stations 5, 8, 9, 10 and 12 which are located at tributaries are not compliance with Class II. WQI of station 7 – 12 which are more nearer to the Bakun Dam are classified in Class III as the chemical oxygen demand and biochemical oxygen demand of them are higher than others. Dissolved oxygen, turbidity, total suspended solids and total sulphide of most of the stations that located at main river are higher than stations at tributaries. Sediment samples are mineral acidic and higher organic matter has recorded with higher weight of water content whereas the total phosphorus and total nitrogen in sediment are 46.53 – 102.86 mg/kg and 0.73 – 6.17 mg/kg.

Key words: Water quality, sediment quality, logging, INWQS, WQI

Kualiti air dan sedimen di Sungai Rajang di Kawasan Pelagus, Sarawak

Phan Tze Pei
Sumber Kimia, Fakulti Sains Sumber dan Teknologi, Universiti Malaysia Sarawak

ABSTRAK

Kajian ini telah dijalankan untuk memeriksa kualiti air dan sedimen di Sungai Rajang di kawasan Pelagus untuk menghasilkan rujukan garis dasar alam sekitar sebelum pembinaan empangan kuasa hidroelektrik yang telah dijadualkan di dalam pelan pembangunan Sarawak. Sampel telah dikumpulkan di 12 stesen di sepanjang Sungai Rajang daripada Pelagus Rapid ke Punan Bah pada 27-28 Ogos 2014 dan 14-15 Januari 2015. Keputusan kajian ini menunjukkan bahawa kualiti air terjejas akibat pembalakan, tumbuh-tumbuhan dan bahan buangan dari isi rumah dan haiwan di seluruh kawasan kajian. Jumlah pepejal terampai dan kekeruhan stesen 1, 5, 6, 7, 10, 11 dan 12 melebihi Kelas II had 50 mg / L manakala oksigen terlarut stesen 1, 6 dan 11 jatuh ke dalam Kelas III (3-5 mg / L) berdasarkan INWQS. Permintaan oksigen biokimia stesen 1, 2, 4, 5, 6, 7, 8, 9, 10, 11 dan 12 tidak dipatuhi Kelas II (1-3 mg / L) manakala permintaan oksigen kimia semua stesen dilampaui Kelas II had 25 mg / L berdasarkan INWQS. Selain itu, jumlah nitrogen ammonia daripada semua stesen kecuali stesen 8 melebihi had Kelas II 0.3 mg / L Menurut WQI, hanya stesen 2, 3, dan 4 anak sungai yang dikelaskan di bawah Kelas II (76.5-92.7) manakala stesen 1, 6 , 7 dan 11 yang terletak di sungai utama dan stesen lain 5, 8, 9, 10 dan 12 yang terletak di anak sungai tidak mematuhi Kelas II. WQI stesen 7-12 yang lebih dekat kepada Empangan Bakun dikelaskan dalam Kelas III kerana permintaan oksigen kimia dan permintaan oksigen biokimia daripada mereka adalah lebih tinggi daripada yang lain. Oksigen, kekeruhan, jumlah pepejal terlarut digantung dan jumlah sulfida kebanyakan stesen yang terletak di sungai utama adalah lebih tinggi daripada stesen di anak sungai. Sampel sedimen adalah mineral berasid dan lebih tinggi bahan organik telah dirakam dengan berat badan yang lebih tinggi daripada kandungan air manakala jumlah fosforus dan jumlah nitrogen dalam sedimen adalah 46.53-102.86 mg / kg dan 0.73-6.17 mg / kg.

.***Kata kunci:*** *Kualiti air, kualiti sedimen, pembalakan, INWQS, WQI*

INTRODUCTION

Water is an important requirement of human life and activities related to industry, agriculture, and others, and it is considers one of the most fragile parts of the environment (Badaii et al., 2013). Quality of water criteria are water characteristics, the levels of individual pollutants or descriptions of conditions of the water body that, if met, will generally protect the designated use (U.S.EPA Science Advisory Board Consultation, 2003). Conserving the river water and sediments quality is important due to the sensitivity of aquatic ecosystem in the river (Ling et al., 2010a). Factors that affect the quality of river water are geologic, climatic and anthropogenic (Meybeck et al., 1996). Anthropogenic pollutants associated with land use causes extreme deterioration of aquatic systems in watersheds and it is the factor that can be controlled to protect the quality of river water (Badaii et al., 2013; Ling et al., 2010b). Livestock wastewater consists of high concentrations of organic and inorganic nitrogen, ammonia nitrogen, and pathogenic bacteria while the runoff of the nutrient rich waste results in depletion of oxygen (Badaii et al., 2013).

River sediments are essential compartments of the aquatic ecosystems because they provide habitat and shelter for many organisms and it also act as a long-term source of contamination, as pollutants can be momentarily unavailable for uptake when bound to particles then released to aquatic phase gradually (Flueck et al., 2010). Sediment is the greatest water pollutants by weight or volume, and the erosion and sedimentation process has many effects throughout our environment (Alabama State Water Program, n. d.). Hence, sediments should not accumulate any persistent pollutants in order to protect the aquatic life (Flueck et al., 2010). In river and streams, habitat for macroinvertebrates and fish spawning are influenced by fine inorganic sediments, especially silts and clay while suspended sediment affects the light available for photosynthesis by plants and visual capacity of animals (U.S.EPA Science Advisory Board Consultation, 2003). We are able to determine the sources and assess the effects of the pollutants on the aquatic environment by analyzing the quantity, quality and characteristic of sediment in streams (Alabama State Water Program, n.d.).

Domestic wastewater was reported to be the main factor in water pollution of Jinshui River in China (Bu et al., 2010). Sullage from Kuching City's residential area was reported to be high in oxygen demand and nutrients like ammonia-nitrogen, reactive phosphorus, total phosphorus and total nitrogen and low in dissolved oxygen (Ling et al., 2010b).

The Rajang River is the longest river in Malaysia. It flows about 563 km to the South China Sea and it is the main drainage system for central Sarawak which originates from the Nieuwenhius Mountain Range and the upper Kapuas mountain that is located in northwest of Borneo (*Encyclopedia Britannica 1911*, n. d.). Rajang River is importance to Sarawak and the rest of Malaysia as logging is the main source of income for Sarawak and it also serve as transportation (Parenti & Lim 2005). Forests Monitor (2006) stated that the construction of logging roads and camps, skid trails and logging itself contribute upstream soil erosion. Therefore, river basins contained extremely high suspended sediment loads and high turbidity (Heyzer, 1996).

Agricultural activities might contaminate the river water as the common agriculture contaminants are nitrate, phosphorus and sulfates; therefore, concentration of nitrate, phosphorus and sulfates will be higher near to the site with agriculture activities (Kumar, 2005).

However, other developments in the watershed such as residential areas and construction may contribute to degradation of the water quality and also impact the survival of aquatic organisms (Ling et al., 2010b). We must limit the sediments in water to safeguard the future of our water resources (U.S.EPA Science Advisory Board Consultation, 2003).

There are a few researches on the fishes of the Rajang basin (Parenti & Lim, 2005), macrofauna of Rajang River (Shabdin, 2010) and modeling of Batang Rejang for extreme Events (Mah et al., 2013). Rajang River at Pelagus area has been scheduled or proposed for hydroelectric power dam in the development plant of Sarawak (Sarawak Integrated Water Resources Management Master Plan, 2008).

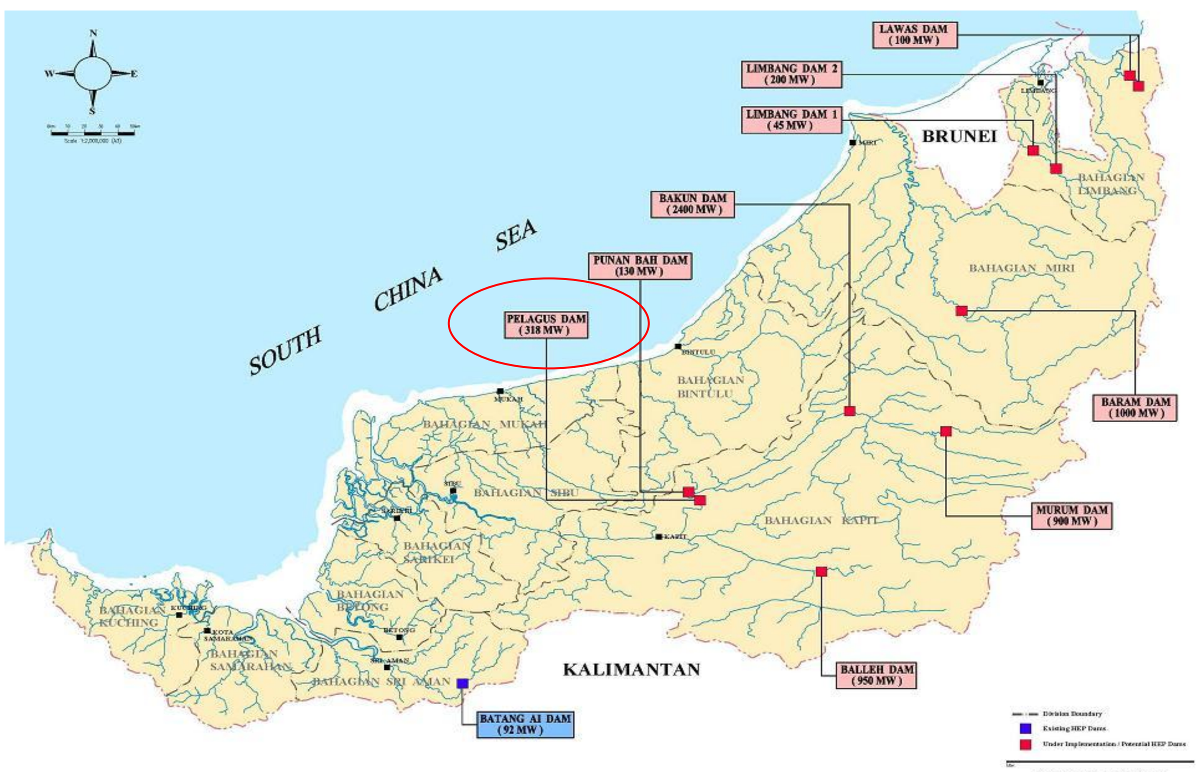

Figure 1: Location of the existing and proposed HEP dams in Sarawak (Sarawak Integrated Water Resources Management Master Plan, 2008).

In this study, all the *in-situ* and *ex-situ* parameters were measured and classified based on Interim National Water Quality Standard (INWQS) to identify the effects of anthropogenic land use activities on the water quality condition. Moreover, the river water was categorized by calculating the sub index of several parameters based on Department of Environment Water Quality Classification Based on Water Quality Index. The objectives of the study are to determine the water and sediments quality, the concentration or contents of nutrients in river water and sediment and total suspended solids in water of Rajang River at Pelagus area, providing the baseline data. Throughout this study to examine the status of the water and evaluate whether the water quality is suitable for aquatic ecosystem and whether treatments are needed to be applied for water supply. Comparison can be made by using this baseline data after the dam construction has finished to evaluate the effect or impact of hydroelectric power on the Pelagus area.

LITERATURE REVIEW

Analysis of water and sediment quality of selected areas in the river identifies areas where the river is likely to become contaminated or polluted due to land use or human activities. The capability of a river system to sustain life depends in part on the water and sediment quality found in the aquatic environment. Quality of water and sediment depend on the characteristics of the river drainage basin (Regional Aquatics Monitoring Program, n. d.).

There are many research studies on the impact of water and sediments quality, impacts of land use on water and sediments quality and water and sediments quality of rivers, reservoirs and dams that have been conducted or done by other researchers. There are a few researches on the fishes of the Rajang basin (Parenti & Lim, 2005), macrofauna of Rajang River (Shabdin, 2010) and modeling of Batang Rejang for extreme Events (Mah et al., 2013). The Rajang is of particular economic importance to Sarawak and the rest of Malaysia (Parenti & Lim, 2005). Logging is a major source of income and is the main activity along the Rajang that serves as the principal means of transportation (Parenti & Lim, 2005).

Water quality *in- situ* measurement

Most research studied the impacts of shrimp farming, domestic wastewater, cage culture and land uses of the river by analyzing the quality of water. The parameters that need to be measured to determine the *in-situ* water qualities are temperature, dissolved oxygen (DO), pH, electrical conductivity (EC), transparency (Tansp) and turbidity (Turb).

Electrical Conductivity

Electrical conductivity is to quantify the capacity of water to conduct electric current and depends upon the ions' number or charged particles in the river water (APHA, 1999). It gives a direct measurement of dissolved ionic matter in the river water (Western Australia Department of Water, 2009). Conductivity in rivers or streams is influenced by the area's geology through which the water flows (USEPA, 2012). Streams that flow through areas with clay soils will have higher conductivity due to the presence of materials that ionize when washed into the water (USEPA, 2012). Small values are characteristic of great quality, low nutrient waters whereas values of high conductance are indicative of salinity problems but also observed in eutrophic waterways where fertilizer (plant nutrients) are in greater quantity

(Western Australia Department of Water, 2009). Generally, most of the freshwaters conductivity is ranging from 10 to 1000 µs/cm (Gandaseca et al., 2011). Conductivity range of distilled water is 0.5 - 3 µs/cm and range outside of 150 - 500 µs/cm is unsuitable for certain species of fish and macroinvertebrates (USEPA, 2012). Conductivity might be increased due to a failing sewage system due to the presence of chloride, phosphate, and nitrate while oil spill would lower the conductivity (USEPA, 2012).

DO

DO measures quantity of oxygen dissolved in an aqueous solution (APHA, 1999). The quantity of oxygen dissolved in water is largely dependent upon the temperature of water; water with low temperature can carry extra dissolved oxygen than water with higher temperature (Western Australia Department of Water, 2009). DO is a significant water quality parameter influencing the health of river and it is important to aquatic life and eco-system, DO concentrations of unpolluted fresh water will be close to 10 mg/L as when DO levels drop below 5 mg/L, detrimental effects may occur (Naik & Manjapp, 2010). Lower DO values from Belaga to Sibu were recorded where the flow became slower and fewer rapids formed when moved downstream (Lau, 2011). The author from the studies of impact of domestic wastewater and aquaculture on Santubong River stated that the increase of current and wave action would have affected and raised the DO values (Ling et al., 2010b). Flowing water will have higher DO value than stagnant water because of its churning (USEPA, 2012). In flowing water, oxygen- rich water at the surface is constantly being replaced by water containing less oxygen as a result of turbulence while stagnant water undergoes less internal mixing, the upper layer of oxygen-rich water will stay at the surface (Water Quality Control, n.d.).

Amount of DO in river water can be influenced by aquatic plants by producing dissolved oxygen during daytime and consume dissolved oxygen overnight (Grand River Conservation Authority, 2014). Low DO level might due to the high discharge of organic pollutants and nutrients into river water which raise the respiration during degradation of organic matter (Yisa & Jimoh, 2010). From the study of total sulphide concentration in the effluent streams, oxygen conditions will be reduced by forming sulphate, thiosulphate and sulphide with the aid of sulphur oxidizing bacteria and lead to higher TS level (Tangri, 2008). Bellingham (n.d.) stated that waters contaminated with fertilizers, suspended material or petroleum waste, microorganisms such as bacteria will break down the contaminants and the oxygen will be consumed, decrease DO level in water.

pH

Concentration of H^+ determine pH of a solution, it shows the alkalinity or acidity of a solution (APHA, 1999). Water is neutral with pH 7; lower pH values show rising acidity, while pH values higher than 7 designate progressively more alkalinity (Western Australia Department of Water, 2009). Range of 6.5 – 8.0 is preferred by largest variety of aquatic animals, pH exceeding the range decreases the diversity in the river by stressing the physiological systems of a large amount of organism and the reproduction (USEPA, 2012). The optimum pH for river is around 7.4 while acidity of water can be raised by acid rain which harmful to immature fish, insect and speeds up the leaching of heavy metals harmful to fish (Grand River Conservation Authority, 2014). Concentration of hydroxide and represented by a pH > 7 will control the alkalinity of natural waters while boron, phosphorus, nitrogen containing compounds and potassium will contribute to an alkaline pH too (Bellingham, n. d.).

The author from the research of effects of domestic wastewater and aquaculture on water quality of Santubong river stated that pH value that reached 8 could be due to anthropogenic input of nutrients that result in more algae photosynthesis and fish feed and faeces that contribute nutrients to alga growth (Ling et al., 2010b). Besides, the emission of fossil fuel to the atmosphere will combine with river water to produce acid (Marlborough District Council, 2015). Lau (2011) stated that the pH of river water will decrease to between 6 – 6.93 in rainy seasons and varied from 7.33 to 7.90 during dry season. Acid produced from decomposition of vegetation debris in the forest floor might be washed down into the river during raining season (Lau, 2011). The higher the pH; the more PO_4^{3-} are formed from the deprotination of HPO_4^{2-}. Unlike total ammonia, phosphate are less soluble and less volatile, therefore, it formed salts with sodium and calcium and accumulate in the sediment falling out from solution. Phosphates in ions in natural water are existed in solution in its ionized form, as salts, in organic form or as a particulate species (Bellingham, n. d.).

$$H_3PO_4 \rightleftharpoons H^+ + H_2PO_4^-$$
$$H_2PO_4^- \rightleftharpoons H^+ + HPO_4^{2-}$$
$$HPO_4^{2-} \rightleftharpoons H^+ + PO_4^{3-}$$

Turbidity

Turbidity in water is due to suspended and colloidal matter like silt, clay, finely divided inorganic and organic matter, and other microscopic organisms and plankton (Grand River Conservation Authority, 2014). It is an asses of the transparency of water body and is a visual measurement that evaluates the light intensity scattered by a water sample with the light intensity that scattered by a standard reference suspension (Western Australia Department of Water, 2009). Turbidity measurements are always used as an indicator of water clarity and predicted total suspended solids in water (Fondriest Enviromental Inc., 2015). Factors that affect turbidity of water are soil erosion, waste discharge, urban runoff, eroding stream banks, construction and logging activities (USEPA, 2012). The flow of stormwater runoff from impervious surfaces rapidly increases stream velocity and increase the erosion rates of streambanks and channels therefore, turbidity is closely related to stream flows and velocity (USEPA, 2012). High turbidity of the water shows high scattering or absorption of incident light by particles (APHA, 1999). Turbidity in drinking water quality standard of Malaysia is 0 - 5.0 NTU (Ministry of Health Malaysia, 2010). In the study of water quality at Batang Rajang at the upstream and downstream of Bakun Dam reported that turbidity ranged from 20 – 46 NTU and 3 – 11 NTU at their tributaries during dry season and ranged between 288 – 442 NTU during raining season (Lau, 2011). The turbidity of the stations in Bakun Hydroelectric Reservoir is majorly due to suspended solids consisting of particles from the eroded soil transported through surface runoff from the logging in watershed upstream (Nyanti et al., 2012). Turbidity of river water at wildlife sanctuary Sibuti mangrove forest, Miri, Sarawak is 10.2 - 15.3 NTU due to high amount of TSS (Gandaseca et al., 2011).

Transparency

Transparency of the river water is measured using secchi disk (USEPA, 2012). Markings will be made at 10 cm intervals in turbid water whereas markings will be made at 50 cm intervals in clearer waters (Western Australia Department of Water, 2009). Water in the major channel of Rajang River is in yellowish color with water transparency of between 4 to 5 cm (Shabdin, 2010). In the study of freshwater fish diversity and composition in Batang Kerang floodplain, Balai Ringin, Sarawak, secchi transparency of brown water is around 63.20

cm while for black water is around 126.30 cm (Rahim et al., 2009). Transparency of water is directly related to turbidity as turbidity is a measure of water clarity (Fondriest Environmental Inc., 2015). Transparency decreases as turbidity increases due to high scattering or absorption of incident light by particles (USEPA, 2012).

Temperature

Water temperature affects the rates of photosynthesis, rates of metabolism and growth of aquatic organisms and lower dissolved oxygen in the river water (Grand River Conservation Authority, 2014). Heat sources and sinks to a water body include evaporative cooling and heat conduction, incident solar radiation, back radiation, thermal dischargers, tributary inflows and groundwater discharge (Western Australia Department of Water, 2009). Weather condition, solar radiation, evaporation, fresh water influx, sampling time and location might affect the increase or decrease of temperature (Western Australia Department of Water, 2009; Badaii et al., 2013). Higher temperature can increase the rate of chemical reaction to dissolve more minerals from rocks which contribute to higher electrical conductivity and warm river water holds less dissolved oxygen than cool water which might influences the biological activities or aquatic life (Chapman & Kimstach, 1996). The studies of water and sediment quality in Selang Sibu River shows the mean temperature range from 29.2 - 31.2 ℃ which is typical of the estuarine water of a typical country and temperature increase seaward (Ling et al., 2012; Nyanti et al., 2012).

Water flow & discharge

The current flow of the river water is directly related to the quantity of water flowing off the watershed into the river channel and it is influenced by the climate or seasons of the year, raising during rainstorm and declining during dry periods (USEPA, 2012). Velocity of river water has direct and indirect effects on biota (Meybeck et al., 1996). Besides, large differences can be observed between porous rocks, clays, marshy soil and fissured rocks. Vegetation also exerts an influence on the generation of river discharge because it largely determines the quantity of surface run-off (Meybeck et al., 1996). Turbidity of water increased with the raised volume of river water release and volume of river water discharge decreases when water is less turbid but high water discharge will not affect pH, DO, EC and temperature of river water (Rak, Said & Moamed, 2010). Moreover, at higher river discharge rate, the ecological effects of a polluted effluent in a river are less harmful (Meybeck et al., 1996). The large swiftly flowing rivers can receive pollution discharges and be little affected (USEPA, 2012). Rapid running streams will cause the sediment suspended longer in the water column and have greater DO value than slow streams (USEPA, 2012). Greatest velocities appear in the centre of the channel but are reduced to zero at the bank by frictional forces exerted by the shallow bank zone and the bank itself (Meybeck et al., 1996). The velocity gradient thus tends to force any influent waters from a tributary, industrial or municipal point source to the side of the river which they entered (Meybeck et al., 1996). Concentration of TSS in rivers increases as a function of flow. Particles are derived from bank, sheet and gully erosion in the watershed and by re-suspension of particles deposited in the river bed (Meybeck et al., 1996). The flow rate of velocity of water body is the main factor in amount of TSS. High velocity water can carry more particles and larger-sized sediment (Murphy, 2007).

TSS

TSS is identified as the fraction of total solids in a water sample (Western Australia Department of Water, 2009). These solids include everything floating in the water, from sediment, silt and sand to plankton and algae and also the organic particle that decomposed from decomposing materials also contribute to the TSS concentration (Fondriest Environmental Inc., 2015). All the wastewater or rubbish might contain food residue, human waste and other solid materials which can raise suspended solids to a stream (Murphy, 2007). TSS is higher as it received input from the on-going construction work in addition to the residential areas (USEPA, 2006). The TSS value of Wildlife Sanctuary Sibuti mangrove forest's river water ranged from 0.00119 - 0.4361 mg/L as TSS is consider as the natural pollutants in surface water and act as land erosion indicator level (Gandaseca et al., 2011). Another research in Semenyih River, Selangor, Malaysia shows that the TSS value during raining season ranged from 11.7 – 58.1 mg/L while it ranged from 10.3 – 446 mg/L and based on INWQS (Badaii et al., 2013). From the study of Water quality and loading of pollutants from shrimp ponds during harvesting at Sarawak, Ling et al. (2010a) reported that high TSS value might be caused by new roads and housing development which results in the removal of vegetation thus exposing the soil to erosion. Lau (2011) stated that the Rajang River are heavily loaded with suspended solid during rainy season and TSS ranged between 460 – 1009 mg/L. The decaying of logs could release suspended organic particles and contributed to amount of TSS (Murphy, 2007). Elevated levels of solids increase turbidity reducing penetration of light at depth within the water column and limit the growth of desirable aquatic plants (Meybeck et al., 1996). High level of TSS reduced the light from passing through the water, photosynthesis slows down. Reduced rates of photosynthesis caused less dissolved oxygen to be released into the water by plants (Murphy, 2007).

SRP

Soluble reactive phosphate is largely a measure of orthophosphate (PO_4^{3-}) (USEPA, 2012). Natural cycling of phosphorus, fertilizers, detergents and soil erosion are the sources of phosphate (Western Australia Department of Water, 2009). Natural range of P- PO_4^{3-} in river is 0.002 – 0.025 mg/L (Meybeck et al., 1996). Ling et al. (2011) stated the stations that near to settlement, household phosphorus from laundry and septic tank discharge might have given rise to high RP value. Another research in Semenyih River examined the concentration of phosphate (PO_4) ranged from 0.08 – 0.95 mg/L during raining season and 0.62 – 1.9 mg/L during dry season, the value generally exceed the normal level of INWQS for Malaysian rivers which is 0.2 mg/L, thus, fall into class V (Badaii et al., 2013). Household waste water which contains detergents (laundry, bathing and washing), fertilizer runoff and toilet flushing that discharge directly into the river are the main reasons of high concentration of phosphate in river water (Bellingham, n. d.). Furthermore, rainfall can cause varying amounts of phosphates to wash from farm soils into nearby waterways too (Oram, 2014). According to Chapman & Kimstach (1996), the higher the pH, the more PO_4^{3-} will form from the deprotination of HPO_4^{2-}.

TP

Phosphorus occurs as inorganic and organic phosphate in aquatic systems (USEPA, 2012). Total phosphorus test examines all classes of phosphorus which are known as orthophosphates (PO_4^{3-}), condensed phosphates (pyro-, meta-, and other polyphosphates), and organic or inorganic forms of phosphorus (APHA, 1999). Phosphorus changes form as it cycles (Figure 2) throughout the aquatic environment, aquatic plants get dissolved inorganic phosphorus and switch to organic phosphorus while animals take in organic phosphorus by consuming animals, aquatic plants or decomposing animal and plant material (USEPA, 2012). Organic phosphorus from animal and plants excrete wastes or die plants and animals descends to the bottom, switches back to inorganic phosphorus via bacterial decomposition then gets back to water column when the bottom is swirled up by anthropogenic activity, chemical interaction, water current or animals (USEPA, 2012). Sources of phosphorus enhancement may include some detergents, runoff from fertilized lawns, disturbed land areas, animal faeces, sewage and some industrial wastes (Western Australia Department of Water, 2009). In streams system, phosphorus cycle will move the phosphorus to downstream as current carries decaying animal and plant tissue and dissolved phosphorus (USEPA, 2012). Loads of total phosphorus upstream from the Hudson impoundment normally exceeded those downstream during the same sampling periods throughout the study (Zimmerman & Savoie, 2013). Ling et al. (2013) stated that the sources of phosphorus are organic phosphorus from human urine and feces and domestic animals. Water bodies that have TP concentration <10 ppb, is considered nutrient-deprived and unable to support huge quantities of algae and aquatic plants while TP concentration >100 ppb classify lakes as highly eutrophic, with great nutrient and algae levels (Minnesota Pollution Control Agency, 2007). Surface waters that have TP concentration maintained at 0.01 – 0.03 mg/L tend to remain unpolluted or uncontaminated by algal blooms (NC SU Water Quality Group, 1976).

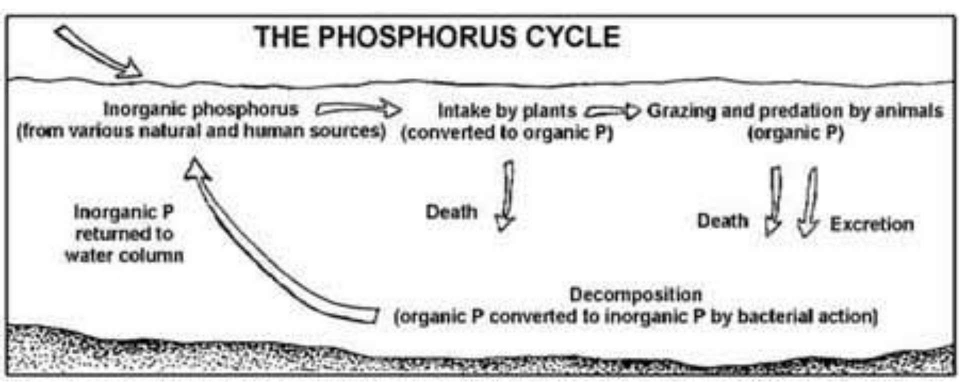

Figure 2: Phosphorus cycle between atmosphere and water

Nitrite & Nitrate

Nitrogen cycle represents one of the most essential nutrient cycles found in terrestrial ecosystem (Figure 3). NO_2^- is an intermediate form of nitrogen and short-lived as it is quickly oxidized to nitrate (APHA, 1999). EPA has set a highest contaminant level at 1 mg/L of nitrite and 10 mg/L of nitrate for drinking water (USEPA, 2012). Nitrite levels are normally low (< 0.01 mg/L) in unpolluted waters (Environment Protective Agency, n.d.). Nitrite may enter the water supply system during its utilize as a deterioration inhibitor in industrial process water (APHA, 1999). Study of Ling et al. (2010b) shows that higher value of NO_2-N might be due to its location near the shrimp farm discharge tributary or cage culture site. NO_3^- is an important plant nutrient and its concentrations in natural waterways are generally low (< 1 mg/L) (Western Australia Department of Water, 2009). Sources of nitrate are manure, agricultural fertilizers, garbage dumps, industrial waste waters, septic system, sanitary landfills and animal feed lots (Minnesota Pollution Control Agency, 2008). Level of nitrate exceed 5 mg/L in natural water generally indicates man made pollution and nitrate level at about 30 mg/L will become toxic to fish (Bellingham, n. d.). Concentration of nitrate in Semenyih River ranged from 4,23 - 8.53 mg/L during raining season while during dry season, it ranged from 1 – 6.3 mg/L and the nitrate values were within maximum permissible limit set by INWQS, Malaysia (Badaii et al., 2013). Another research shows there is a higher value of NO_3-N in the river water near to the construction and residential areas or shrimp culture site (Ling et al., 2010b).

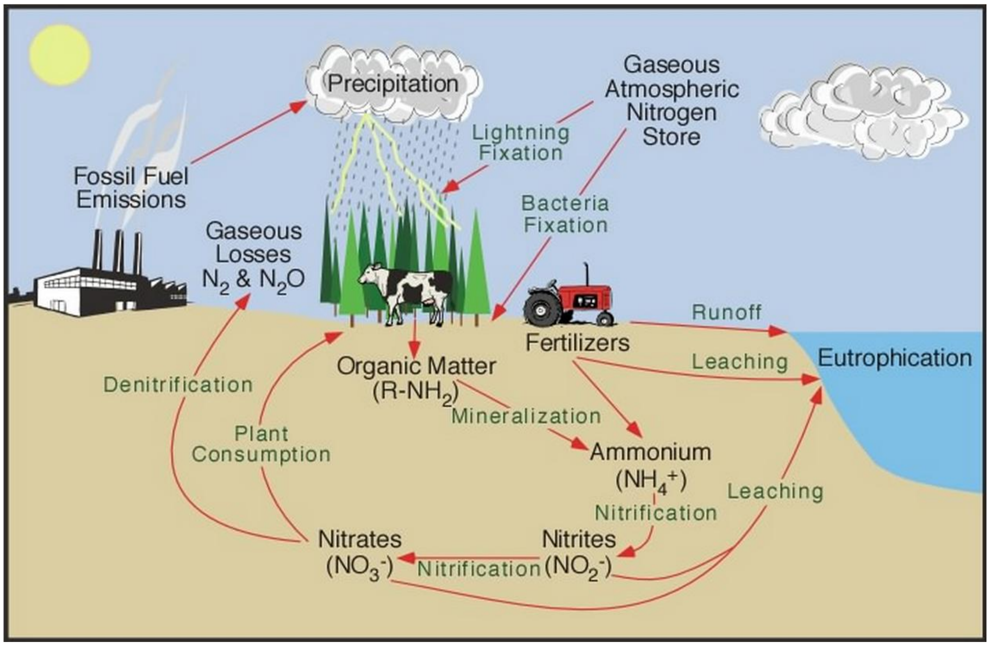

Figure 3: Nitrogen cycle (Pidwirny, 2006).

TAN

TAN is the total amount of ammonia nitrogen and ammonium nitrogen species which exist in equilibrium in aqueous solution (APHA, 1999). Decomposition of organic waste matter, fertilizers, gas exchange with atmosphere, animal and human waste are sources of ammonia (Western Australia Department of Water, 2009; USEPA, 2013). In, addition, higher concentrations could be an indicator of organic pollution (domestic waste) (Chapman & Kimstach, 1996). Unpolluted natural water contain very small amount of ammonia (< 0.02 mg/L as N) (Environment Protective Agency, n. d.). Ammonia concentration that exceeded the recommended limit might harm the aquatic life in the river (Gandaseca et al., 2011). The limited value of ammonia in water bodies class II are 3.7 mg/L NH_3-N to pH < 7.5 and 2 mg/L NH_3 –N to pH > 7.5 (Braz, 2009). Ammonia will be the predominate form at higher pH and ammonia ion will be predominate at lower pH. As the pH increases, unionized ammonia, NH_3 is much more volatile than ionized form and will leave the aqueous solution by volatilization.