Environmental Parameters of Coastal Waters in Three National Parks of Southern Sarawak

Faddrine Holt Ajon Jang

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Environmental Parameters of Coastal Waters in Three National Parks of Southern Sarawak

Faddrine Holt Ajon Jang

This thesis is submitted in fulfillment of the requirements for the Degree of Master of Science in Marine Science

Faculty of Resource Science and Technology
UNIVERSITI MALAYSIA SARAWAK
2015
DECLARATION

I hereby declare no portion of the work referred to this dissertation has been submitted in support of an application for another degree or qualification of this or any other university or institution of higher learning.

__________________________________________
(FADDRIE HOLT AJON JANG)
2015

Department of Aquatic Science
Faculty of Resource Science and Technology
Universiti Malaysia Sarawak (UNIMAS)
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Thank you very much. God bless.
Inefficient and irresponsible anthropogenic discharges from the intensified urbanization and development into water environment have caused severe degradation to aquatic ecosystem. Sarawak’s coastal waters especially are highly exposed to pollutants from aqua-agricultural activities, domestic waste, discharges by shipping vessels leakages and disposal of engine oils, and high sedimentation rate. In long term effects, these would indirectly lead to the depleting of coastal resources and loss of biodiversity. In this study, in-situ and ex-situ water environmental parameters, and heavy metals concentration distribution were measured at Talang-Satang National Park (including Sampadi Island), Maludam National Park and Kuching Wetland National Park from March 2013 to June 2014. Results from the study indicated that water temperature and pH were classified under Class I, ranging from 26 – 30 °C and pH 7 – 8 respectively. Meanwhile, turbidity (0 – 3 NTU), dissolved oxygen (DO) (5 – 9 mg/L) and total suspended solid (TSS) (0.00 – 0.50 mg/L) for all sites were under Class I except for Kuching Wetland National Park’s which were under Class V, and IV (E) respectively. Whereas, nutrients (nitrate and orthophosphate) of all sites fell under Class 3, and nitrite was under Class I. Talang Talang Island showed rather contradicting results in heavy metal levels with Satang Island despite their establishment together as one National Park. Most of Talang Talang Island’s heavy metals (As, Cu, Pb and Zn) were classified under Class 3 while Satang Island’s were within Class 1 and 2. Kuching Wetland National Park and Maludam National Park both bear resemblance in heavy metal levels that most of them were classified under Class 2 and 3 (As, Cu, Pb and Zn). Manganese and Nickel levels of all sites were under Class I and IIA/IIB respectively, except for Nickel of Kuching Wetland National Park (Class I). The unforeseen high heavy metal levels in Talang Talang Island regardless of its protected marine park status was awfully concerning. The land-based anthropogenic input and aqua-agricultural activities within its proximity contributed most of the pollutants and definitely affecting the water quality. On the other hand, an immense population residing alongside both Kuching Wetland National Park and Maludam National Park certainly affected the water quality at respective sites. It can be concluded here how water environment is one fragile ecosystem. Therefore, continuous water environmental parameters study and monitoring is significant as to supply rapid assessments of water quality; prior to detection of pollution influx and indirect manifestation in living organisms. Ergo, an optimization of coastal development and socio-economic growth while sustaining and preserving targeted natural resources is significant, and that it involves various efforts from all parties.

Keywords: In-situ, ex-situ, nutrients, heavy metals, anthropogenic
Parameter Alam Sekitar Persisiran Pantai Di Tiga Taman Negara Selatan Sarawak

Fadderne Holt Ajon Jang

ABSTRAK

Ekoran daripada hasil pembangunan dan pembandaran yang dipergiatkan, pembuangan sisa antropogenik ke dalam persekitaran air secara tidak bertanggungjawab akan menyebabkan degradasi kepada ekosistem akuatik. Persisiran pantai Sarawak terdedah kepada pencemar dari aktiviti akuakultur, pertanian, sisa domestik, kebocoran perkapalan dan minyak enjin, dan kadar pemendapan yang tinggi. Dalam kesan jangka panjang, secara tidak langsung ini akan menyebabkan kekurangan sumber pantai dan biodiversiti. Dalam kajian ini, parameter persekitaran in-situ dan ex-situ serta taburan konsentrasi logam berat diukur di Taman Negara Talang-Satang (termasuk Pulau Sampadi), Taman Negara Maludam dan Taman Negara Kuching Wetlands; bermula Mac 2013 sehingga Jun 2014. Hasil kajian menunjukkan suhu dan pH air dikelaskan dalam Kelas I, di mana suhu air berada dalam julat 26 – 30 °C manakala pH berada dalam julat pH 7 – 8. Sementara itu, kekeruhan air (0 – 3 NTU), oksigen terlarut (5 – 9 mg/L) dan jumlah pepejal terampai (0.00 – 0.50 mg/L) untuk semua tapak kajian dikelaskan dalam Kelas I; kecuali untuk Taman Negara Kuching Wetlands yang mana dikategorikan bawah Kelas V dan IV (E). Manakala, nutrien (nitrat dan ortofosfat) bagi semua tapak kajian dikelaskan dalam Kelas 3, dan nitrat dalam Kelas I. Pulau Talang Talang menunjukkan konsentrasi logam berat yang agak bercanggah dengan Pulau Satang meskipun ditubuhkan bersama sebagai sebuah Taman Negara. Kebanyakan logam berat di Pulau Talang (As, Cu, Pb dan Zn) dikelaskan di bawah Kelas 3, manakala bagi Pulau Satang logam berat tersebut berada di dalam Kelas 1 dan 2. Taman Negara Kuching Wetland dan Taman Negara Maludam menunjukkan persamaan dalam konsentrasi logam berat, yang mana kebanyakkannya dikelaskan dalam Kelas 2 dan 3 (As, Cu, Pb dan Zn). Konsentrasi Mangan (Manganese) bagi semua tapak kajian dikelaskan dalam Kelas I; manakala Nikel dalam Kelas IIA/IB, kecuali Nikel bagi Taman Negara Kuching Wetland (Kelas I). Konsentrasi logam berat yang tinggi di Pulau Talang Talang meskipun mempunyai status sebagai taman laut terlindung, sangat membimbangkan. Input antropogenik, serta aktiviti akuakultur dan pertanian yang berdekaan menyumbang kebanyakan pencemaran dan semestinya mempengaruhi kualiti air. Di samping itu, kadar populasi yang tinggi sepanjang sisi Taman Negara Kuching Wetland serta Taman Negara Maludam turut mempengaruhi kualiti air di tapak-tapak kajian. Dapat disimpulkan di sini bahawa persekitaran air merupakan satu ekosistem yang rapuh. Oleh itu, kajian serta pemantauan parameter persekitaran air adalah penting bagi penilaian kualiti air yang pantas; sebelum pengesanan pencemaran dan seterusnya manifestasi tidak langsung ke dalam organisma hidup. Pengoptimuman pembangunan persisiran pantai serta pertumbuhan sosio-ekonomik sementara memelihara dan mengekalkan sumber semula jadi adalah penting, dan ini melibatkan pelbagai usaha dari pelbagai pihak.

Kata kunci : In-situ, ex-situ, nutrien, logam berat, antropogenik
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<td>BOD</td>
<td>Biochemical Oxygen Demand</td>
</tr>
<tr>
<td>DO</td>
<td>Dissolved Oxygen</td>
</tr>
<tr>
<td>pH</td>
<td>Potential of Hydrogen</td>
</tr>
<tr>
<td>TSS</td>
<td>Total Suspended Solid</td>
</tr>
<tr>
<td>As</td>
<td>Arsenic</td>
</tr>
<tr>
<td>Cu</td>
<td>Copper</td>
</tr>
<tr>
<td>Mn</td>
<td>Manganese</td>
</tr>
<tr>
<td>Ni</td>
<td>Nickel</td>
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<tr>
<td>Pb</td>
<td>Lead</td>
</tr>
<tr>
<td>Zn</td>
<td>Zinc</td>
</tr>
<tr>
<td>km</td>
<td>Kilometer</td>
</tr>
<tr>
<td>L</td>
<td>Liter</td>
</tr>
<tr>
<td>m</td>
<td>Meter</td>
</tr>
<tr>
<td>mg/L</td>
<td>Miligram per Liter</td>
</tr>
<tr>
<td>NTU</td>
<td>Nephelometric Turbidity Unit</td>
</tr>
<tr>
<td>PSU</td>
<td>Practical Salinity Unit</td>
</tr>
<tr>
<td>AAS</td>
<td>Atomic Absorption Spectrophotometer</td>
</tr>
<tr>
<td>DOE</td>
<td>Department of Environment</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System</td>
</tr>
<tr>
<td>INWQS</td>
<td>Proposed Interim National Water Quality Standards</td>
</tr>
<tr>
<td>KWNP</td>
<td>Kuching Wetland National Park</td>
</tr>
<tr>
<td>MNP</td>
<td>Maludam National Park</td>
</tr>
<tr>
<td>MWQS</td>
<td>Marine Water Quality Criteria &amp; Standard</td>
</tr>
<tr>
<td>NREB</td>
<td>Natural Resources and Environment Board</td>
</tr>
<tr>
<td>TSNP</td>
<td>Talang Satang National Park</td>
</tr>
<tr>
<td>WQI</td>
<td>Water Quality Index</td>
</tr>
<tr>
<td>HCl</td>
<td>Hydrochloric Acid</td>
</tr>
<tr>
<td>HNO₃</td>
<td>Nitric Acid</td>
</tr>
<tr>
<td>NH₃-N</td>
<td>Ammonia Nitrogen</td>
</tr>
<tr>
<td>NO₂⁻</td>
<td>Nitrite</td>
</tr>
<tr>
<td>NO₃⁻</td>
<td>Nitrate</td>
</tr>
<tr>
<td>PO₄³⁻</td>
<td>Orthophosphate</td>
</tr>
<tr>
<td>µg/L</td>
<td>Microgram per Liter</td>
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<tr>
<td>°C</td>
<td>Degree Celcius</td>
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CHAPTER 1
1.0 INTRODUCTION

Inevitable natural processes such as precipitation inputs, soil erosion/leaching, and weathering of crust materials cause an ever-increasing exploitation of water resources apart from the anthropogenic influences, industrial and agricultural activities (Nair et al., 2003; Prasanna and Ranjan, 2010; Soo et al., 2014). The release of both anthropogenic and natural effluents may degrade the water quality too which might lead to Harmful Algal Blooms (HAB) if not controlled and monitored properly. Not only it endangers human beings, it also brings about detrimental impacts to the aquatic ecosystem.

Apart from pollution, heavy metal contamination in water system also is one of the biggest concerns in Malaysia due to their environmental persistence, biogeochemical recycling and ecological risks (Alkarkhi and Ahmad, 2009). Heavy metals can be toxic if available exceeding the minimum requirements, although some of them are fundamentally required as micronutrients (Rizal, 2006). Most metals in water bodies exist in trace amounts and they occurred naturally due to weathering of rocks and further magnified by absorption processes of naturally occurring soil components (Haroun et al., 2007).

These issues were further worsen since the elevating pressure from development presents imperative challenges for coastal management strategies aimed at sustainable development (Dada et al., 2012). The conductance of environmental parameters studies are prominent due to the fact that they can be further applied to various studies of varying fields, such as coral reefs, phytoplankton and the local biodiversity of the sampling sites. Environmental parameters study which also encompasses water quality research involves
ongoing regular supervision of a water body to determine the influence of land-based pollutions due to the increase in urbanisation and development.

1.1 Environmental Parameters: The Significance, Studies and Its Effort in Malaysia

Environmental parameters study is a wider scope of water quality research since it is inclusive of physico-chemical properties of water and heavy metals concentration distribution. According to the Department of Environment (DOE), this study is fundamental in providing basic information on the degree of pollution from land-based sources and their ability in supporting diverse habitats and wide range of marine species.

The primary rationale to environmental parameters study is to sustain and protect designated uses of water, while maintaining and supporting aquatic life and functioning for aquatic ecosystems. This includes human consumption, livestock watering, irrigation, fisheries and agricultural purposes and recreation.

Despite the recurrent debate on its ability in measuring an ecosystem’s environmental health; it is somehow acknowledged how it fundamentally supplies rapid assessment of the environmental quality prior to manifestation in living organisms (Yap et al., 2006). Furthermore, early detection of pollution influx could be detected through continuous monitoring (DOE, 2004). Any specified parameter which is out of tolerance range could be considered as being detrimental to the living organisms.

The Water Quality Index (WQI) was introduced by the DOE and it integrates complex data to generate a score that describes the status of water quality to the public as well as decision and policy makers (Massoud, 2011). The WQI is generally used to assess river water
quality consisting of environmental parameters such as dissolved oxygen (DO), biochemical oxygen demand (BOD₅), chemical oxygen demand (COD), ammoniacal nitrogen (NH₃N), suspended solids (SS), pH, conductivity, turbidity, salinity and temperature (DOE, 2004). It is however inapplicable for marine and estuarine water due to the conflicting parameter ranges of the ecosystems. Therefore, Malaysia Marine Water Quality Criteria & Standard (MWQS) and Proposed National Water Quality Standards for Malaysia (INWQS) both by the DOE were utilized whereby comparison with baseline data was done.

In Malaysia, marine environmental parameters monitoring effort (conducted by the DOE) was started in peninsular Malaysia and Sabah and Sarawak at 1978 and 1985 respectively (DOE, 2011). In Sarawak, the responsibilities of environmental parameters monitoring are conducted by both the DOE and Natural Resource and Environmental Board (NREB). And the most frequent environmental parameters measured are those related to water pollution due to anthropogenic factors, namely, land clearing, sewage discharge and industrial effluents.

In this study; pollution control, water supply and efficient sewerage system are parts of co-dependent elements of water resources management (Muyibi et al., 2007) ergo validating how its monitoring is a subject of ongoing concern and research (Massoud, 2011). An appropriate monitoring is significant to be conducted for future planning references and management of clean water resources (Ghumman, 2011) besides utilized in designing control strategies in order to achieve better environmental quality as well as a key role to efficient management. In addition, planning, zoning and controlling besides appropriate management, legislation and effective enforcement can help to optimize coastal development and socio-
economic growth while sustaining and preserving targeted natural resources (Jakobsen et al., 2007; Mukherjee et al., 2011).

1.2 *In-situ* and *Ex-situ* Water Environmental Parameters

Water environmental parameters such as temperature, salinity, DO, turbidity and pH can potentially influence the fate of contaminants in water body; control their speciation and therefore their distribution within the dissolved or particulate fractions (Yap et al., 2006). In addition, these parameters can be used to indicate pollution level of the water body.

Table 1.1 List and Summary of *In-Situ* and *Ex-Situ* Parameters

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>DEFINITIONS, FUNCTIONS &amp; FACTS</th>
<th>CITATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>Definition: A measurement of the intensity of the heat, not the quantity. Plays crucial role in influencing both chemical and biological processes. When sunlight warms up the surface water, with an assumption of standardized density, the denser cold water sinks below warm water. An increase in water temperature may bring about detrimental physical and biological impacts to the marine organisms whereby it modifies the distribution of marine and freshwater species, changes in habitat size and productivity, ecosystem productivity declines in tropical and subtropical regions, and affecting the fish physiology. Thermal pollution is an extreme increase in water temperature caused by adding warm water into the aquatic environment from power plants, industrial factories, and streets and pavements runoffs.</td>
<td>(Stewart, 2008) (Nyanti, 2012; Tait, 2014)</td>
</tr>
<tr>
<td>pH</td>
<td>Definition: The pH of a solution is the concentration of hydrogen ions. Expressed as a negative logarithm, it reflects the acidity or alkalinity of the water column. pH value lower than 7 is classified as acidic whereas, pH value higher than 7 is considered as basic or alkaline. pH 7 portrays neutrality.</td>
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</table>
pH of a water body may be altered due to acid mine drainage, poorly regulated acids or bases in industrial effluents or atmospheric depositions.

High or low pH values affect aquatic life and are able to alter the toxicity of pollutants from one form to another besides the solubility of elements such as Al, Cu, Cd, Fe and Mn. (Greaney, 2005; Akan, 2008; Gasim et al., 2013)

In certain cases, pH level may elevate due to the photosynthetic algae activities that consume carbon dioxide (CO₂) dissolved in water. (Gandaseca et al., 2011)

There is no such normal pH that applies to the aquatic organisms since varying organisms originate in ponds, lakes, rivers, oceans which have different pH levels. However, an abrupt change in pH can be harmful and fatal to them. (Chakraborty et al., 2013)

<table>
<thead>
<tr>
<th>Salinity</th>
<th>Definition: The measure of concentration or mass of dissolved salt in a water body (sample). Unit for salinity is parts per thousand (ppt) which can also be donated by the symbol %‰ (per mille) or (PSU).</th>
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<tr>
<td></td>
<td>Salinity variability is the most outstanding characteristic which distinguishes seawater with freshwaters such as lakes, rivers and streams that it varies considerably over seasons and times.</td>
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<td>Salinity is considered as an ecological factor of considerable importance, due to its ability of affecting the types of organisms inhabiting the water body, whereby they are called euryhaline species due to their exceptional ability to withstand wide range of salinity changes.</td>
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<td></td>
<td>Changes in salinity are a result of naturally or seasonally occurring variations in evaporation and freshwater flow rate, however this can be escalated by human influence.</td>
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</table>

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<tr>
<th>Turbidity</th>
<th>Definition¹: An optical measurement measuring the scattering effect that suspended solids have on light. The higher the intensity of scattered light, the higher the turbidity.</th>
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<tbody>
<tr>
<td></td>
<td>Definition²:A measure of the clarity of a water body that compares the intensity of light scattered by a water sample with the intensity of light scattered by a standard reference suspension.</td>
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<td></td>
<td>Recorded in Nephelometric Turbidity Unit (NTU) or Formazin Turbidity Unit (FTU).</td>
</tr>
<tr>
<td></td>
<td>The presence of soluble colored organic matter and suspended inorganic particles such as silt, clay, plankton and microscopic</td>
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</table>
organisms cause the increase in turbidity. A high turbidity of water body too may be due to the occurrence of mixing and stratification processes. 

The increase in turbidity reduces light intensity penetrating water body and leads to declining photosynthetic rate. 

Major contributors to turbidity are suspended particles, mainly clay, silt, organic matters and microorganisms. 

<table>
<thead>
<tr>
<th>Dissolved Oxygen (DO)</th>
<th>Definition: The amount of oxygen dissolved in water and is particularly vital in limnology (aquatic ecology).</th>
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<tbody>
<tr>
<td></td>
<td>Rich DO concentration within one ecosystem helps to support diverse aquatic lives whereas the lack of its content (deoxygenated condition, hypoxia) causes inhibition to higher forms of flora and fauna.</td>
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<td></td>
<td>Hypoxia, a severe symptom of eutrophication, is a condition whereby oxygen concentration supply is cut off, or when the consumption rate exceeds the resupply, and the concentration declines below optimal level. Hypoxia is commonly caused by the death of algae which would sink to the bottom and subsequently decomposed by bacteria (whereby the bacteria consume the dissolved oxygen).</td>
</tr>
<tr>
<td></td>
<td>Oxygen concentrations are the product of; oxygen consumption caused by remineralization of organic matter, oxygen inputs by oxygen fluxes across the air-water interface, and by photosynthesis of organic matter.</td>
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<td></td>
<td>DO is an essential biogeochemical component in water quality and is utilized as a key supporting element in assessing ecological status of marine and estuarine environments, ergo, a significant ecosystem health indicator.</td>
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<td></td>
<td>Due to its association with the amount of rainfall and freshwater discharge into the backwater, DO is classified as a seasonal fluctuation parameter in the environment. DO plays a vital role in the ecosystem as it is required in respiration of aquatic organisms, and the cycle is completed by photosynthetic organisms producing DO through photosynthesis but only with the presence of adequate light and nutrients.</td>
</tr>
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<td></td>
<td>However, the influences of nutrient rich sediment from anthropogenic sources cause the primary production life cycles to bloom and eventually decay. The decomposition of organic matter would eventually remove the DO from the water, subsequently creating hypoxic or anoxic zones.</td>
</tr>
<tr>
<td></td>
<td>Other than that, the amount of oxygen that can be held by water</td>
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</tbody>
</table>

(Gandaseca et al., 2011; Gasim et al., 2013) (Yap et al., 2002) (Diaz et al., 2012) (Rixen et al., 2010) (O’Boyle et al., 2009; Greenwood et al., 2010)
The amount of DO in water is increased by means of mixing processes such as rain, wind and waves on the surface which helps to mix the air with water (aeration). Precipitation and photosynthesis by chlorophyll-containing aquatic organisms too increases the amount of DO in water.

DO concentration naturally is found in saturation degree within the euphotic layer and gradually decrease towards the thermocline concentration layer.

Meanwhile, decomposition processes of organic wastes by bacteria reduce the concentration of DO in water. Oxygen depletion in bottom water especially in water with weak tidal movement may damage the benthic ecosystem besides probability of influencing the solubility of phosphorus and other inorganic nutrients.

| **Biochemical Oxygen Demand (BOD₅)** | Definition: Amount of dissolved oxygen required by variety of microorganisms to decompose organic matters into simpler substances. BOD₅ can be used in determining the amount of concentration of organic matter present. However, it should be noticed that BOD₅ itself does not measure the pollutants level of the water body, but in a way, it indicates the amount of oxygen requirement needed by microorganisms to stabilize the organic matter. A high BOD in contrary with low DO level signifies contamination of the water body that is either caused by the inflow of wastes from terrestrial run-off or from anthropogenic sources. BOD₅ measures the strength of sewage concentration whereby it increases when there is a high concentration of organic matter such as leaves, woods, wastewater or urban storm water run-off that took place in the water body. | (Gandaseca et al., 2011) |
| **Chlorophyll-a** | Definition: A type of green pigment found in photosynthetic plants which play crucial roles in photosynthesis. It converts sunlight and CO₂ into organic compounds (eg. carbohydrate) while generating by-products such as O₂ through photosynthesis. The concentration of chlorophyll-a can be used to indicate phytoplankton abundance and biomass in water body. And an excessive concentration of chlorophyll-a in water body may cause reduced water clarity, low DO concentration, food supply imbalance and production of species deemed potentially harmful to aquatic life. | (KDHE, 2011) | (USEPA, 2007; KDHE, 2011) |
A high concentration of chlorophyll-\(a\) in a water body signifies low water quality, whereas a lower concentration indicates a good water quality.

High levels of chlorophyll-\(a\) besides excessive seaweed and epiphyte blooms is considered as one of the symptoms to eutrophication. (Bricker et al., 2003)

**Total Suspended Solid (TSS)**

Definition: The amount of solid particles (which include soluble colored organic matter and suspended inorganic particles such as silt, clay, plankton and microscopic organisms) suspended within the water body/sample.

TSS in marine waters is used as an indicator of land-based activities such as uncontrolled land clearing, agriculture and coastal development; and remained as one of the significant contaminants of marine waters. (DOE, 2008)

Major component of TSS includes soil and sediments, which are the ultimate sink for numerous anthropogenic-based contaminants from agricultural, industrial, urban and recreational effluents. Not only they cause high siltation and sedimentation rates, soil and sediments are also mediums and transmitter of pollutants into water environment. Sediments are mainly recognized as the significant sink to varying pollutants in aquatic ecosystem, and also as potential non-point sources of pollutants which might directly and indirectly affect the overlying water. (Adamu, 2010; Zulkifli et al., 2010)

According to Maipol (2001), one of the most common yet vital factors in marine parks’ water quality degradations was high rate of sedimentation whereby in Sabah, most islands such as Gaya, Manukan, Mamutik and Sulug Islands were facing the same predicament. Furthermore, marine parks are generally located within coastal environments therefore are greatly exposed to waves and tidal actions. (Sekiguchi et al., 2008)

Deforestation from both agricultural and aquaculture activities increase soil erosion which leads to high sedimentation rates. And excessive sedimentation due to solids and colloidal materials from overburden could bury coral reefs and other benthic organisms. (Mkuula, 1993; Jakobsen et al., 2007; Liu et al., 2012)

<table>
<thead>
<tr>
<th>Nutrients:</th>
<th>Nutrients contained in run-off from agricultural activities and sewage effluent may bring about detrimental impacts to wildlife and humans if they enter our waterways in exceedingly high levels.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Nitrate</td>
<td>For instance, high levels of ammonia in estuarine can be toxic to fish whereas, high concentrations of phosphates and nitrates may cause excessive algal growth.</td>
</tr>
<tr>
<td>2. Nitrite</td>
<td></td>
</tr>
<tr>
<td>3. Orthophosphate</td>
<td></td>
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<tr>
<td>4. Ammonia-Nitrogen</td>
<td>(Dudley, 2003; Liu et al., 2012)</td>
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