
**Faculty of Resource Science and Technology**

# WATER AND SEDIMENT QUALITY IN THE UPPER REACHES OF THE SAMPADI RIVER

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Bachelor of Science with Honours
(Resource Chemistry)
2012

## Declaration

**No portion of the work referred to this dissertation has been submitted in support of and application of another degree of qualification of this or any other university or institution of higher learning.**

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This project is submitted in partial fulfilment of

the requirement for the degree of Bachelor of Science with Honours

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## List of Abbreviations

| | |
|---|---|
| µm | Micrometer |
| $BOD_5$ | Five-day Biochemical Oxygen Demand |
| Ca | Calcium |
| $CaCl_2$ | Calcium Chloride |
| Cd | Cadmium |
| cm | Centimeter |
| Cr | Chromium |
| Cu | Copper |
| dm | Decimeter |
| FAAS | Flame Atomic Absorption Spectroscopy |
| FAS | Ferrous Ammonium Sulphate |
| Fe | Iron |
| g | Gram |
| $H_2O_2$ | Hydrogen Peroxide |
| $H_2SO_4$ | Sulphuric Acid |
| $H_3BO_3$ | Boric Acid |
| HCl | Hydrochloric Acid |
| $HClO_4$ | Perchloric Acid |
| $HNO_3$ | Nitric Acid |
| km | Kilometer |
| L | Liter |
| L.O.I. | Loss-On-Ignition |
| m | Meter |
| Mg | Magnesium |
| mg | Milligram |
| mL | Milliliter |
| Mn | Manganese |

| | |
|---|---|
| N | Nitrogen |
| $Na_2SO_4$ | Sodium Sulfate |
| NaOH | Sodium Hydroxide |
| $NH_3$-N | Ammonia Nitrogen |
| $NH_4^+$ | Ammonium |
| Ni | Nickel |
| nm | Nanometer |
| $NO_2^-$ | Nitrite |
| $NO_3^-$ | Nitrate |
| O&G | Oils and Greases |
| P | Phosphorus |
| Pb | Lead |
| $PO_4^{3-}$-P | Orthophosphate |
| POME | Palm Oil Mill Effluent |
| PSA | Particle Size Analysis |
| s | Second |
| SPSS | Statistical Programme for Social Sciences |
| TKN | Total Kjeldahl Nitrogen |
| TN | Total Nitrogen |
| TOC | Total Organic Carbon |
| TP | Total Phosphorus |
| TSS | Total Suspended Solids |
| Zn | Zinc |

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# Water and Sediment Quality in the Upper Reaches of the Sampadi River

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## Abstract

This study was done to identify the water and sediment quality at the upper reaches of the Sampadi River where only few stations had been monitored before. There are oil palm plantations and mill, some residential areas and coal refinery situated at the upper reaches of this river. Sampling was done during low tide and high tide conditions. Total suspended solids (TSS) concentration was high during low tide which ranged from 39.93-56.07 mg/L. Nitrate and nitrite nitrogen also show higher concentrations during low tide. However, five-day biochemical oxygen demand ($BOD_5$), total Kjeldahl nitrogen (TKN) and ammonia nitrogen concentration were found higher in high tide condition. $BOD_5$ ranged from 2.81 to 5.02 mg/L during high tide while it ranged from 1.78 to 4.30 mg/L during low tide. TKN and ammonia nitrogen were found to be high in Station 2 and 3 during low and high tide, respectively. This is due to the nutrients input from the oil palm plantation at Chupin Besar River. However, based on the National Water Quality Standard of Malaysia, most of the water quality parameters in stations was categorised under Class I and II. Meanwhile, oil and grease is categorized in Class 3 and for nitrate nitrogen, nitrite nitrogen and phosphorus in water, they are categorized in Class 2 and Class E of the Malaysia Marine Water Quality Criteria and Standard. As for sediment quality in this river, it is influenced by the particle size distribution in the stations where finer particles like silt showed higher total organic carbon (TOC) percentage, heavy metals and nutrients concentrations. There are significant negative correlations between sand and TOC (r=-0.933); between sand and TKN (r=-0.689); and between sand and total phosphorus (r=-0.970).

Keywords: Oil Palm Plantations and Mill, Water quality, Sediment quality, Standard Methods, Sampadi River.

## Abstrak

*Kajian ini dilakukan untuk mengenalpasti kualiti air dan tanah di hulu Sungai Sampadi yang hanya dipantau pada beberapa lokasi sebelum ini. Terdapat ladang dan kilang kelapa sawit beberapa kawasan perumahan dan kilang arang batu yang terletak di kawasan hulu sungai ini. Pengambilan sampel telah dilakukan semasa air surut dan air pasang. Jumlah kepekatan pepejal terampai (TSS) adalah lebih tinggi semasa air surut yang berjulat daripada 39.93-56.07 mg/L. Nitrogen nitrat dan nitrit juga menunjukkan kepekatan yang tinggi semasa air surut. Walau bagaimanapun, kepekatan untuk permintaan oksigen biokimia lima hari ($BOD_5$), jumlah Kjeldahl nitrogen (TKN) dan nitrogen ammonia didapati tinggi dalam keadaan air pasang. $BOD_5$ adalah diantara 2.81 hingga 5.02 mg/L semasa air pasang, manakala diantara 1.78 hingga 4.30 mg/L semasa air surut. TKN dan nitrogen ammonia didapati tinggi di Stesen 2 (air surut) dan 3 (air pasang). Ini disebabkan oleh input nutrien dari ladang kelapa sawit di Sungai Chupin Besar. Walau bagaimanapun, berdasarkan Standard Kualiti Air Kebangsaan di Malaysia, hampir semua parameter kualiti air di setiap stesen menunjukkan kualiti pada kelas I dan II. Sementara itu, minyak dan gris dikategorikan dalam Kelas 3 dan nitrogen nitrat, nitrogen nitrit dan fosforus dalam air, adalah dikategorikan dalam Kelas 2 dan Kelas E berdasarkan Malaysia Marine Water Quality Criteria and Standard. Bagi kualiti tanah di sungai ini, ia dipengaruhi oleh taburan saiz zarah tanah di stesen tersebut dimana zarah yang lebih halus seperti kelodak akan mempunyai peratusan total organic karbon (TOC) yang lebih tinggi serta kepekatan logam dan fosforus yang tinggi. Terdapat hubungan yang signifikan negatif antara pasir dan TOC (r=-0.933); pasir dan TKN (r=-0.689); dan pasir dan total fosforus (r=-0.970).*

*Kata kunci: Ladang dan Kilang Kelapa Sawit, Kualiti Air, Kualiti Tanah, Kaedah Piawai, Sungai Sampadi.*

## 1.0 Introduction

As mentioned by Hynes (1970) forty years ago that human activities has drastically affected rivers and streams in all part of the world and it is now difficult to find any unpolluted or undisturbed rivers and streams. The pollution of aquatic environment is mostly caused by human who have directly or indirectly contributed to the deleterious effects which might cause harm to the biological resources and hazards to human health (Giller & Malmqvist, 1998). Pollutants in the river occur when any substances, either naturally occur substance or human disposal substance, that are added into the river and this can alter the characteristic of that river and its catchment.

The purpose of this research was to examine the water and sediment quality of the Sampadi River. This research was conducted in the upper reaches of the Sampadi River that is located near the area of oil palm plantation. Development activities had been going on near the river such as the oil palm plantation and mill, coal refinery and also some residential areas that might contribute to the degradation of the water and sediment quality at that area.

The use of pesticides, herbicides and fertilizers in the plantation of oil palm plus the discharge of the wastewater that is running through the plantation areas to the river will affect the quality of the river where it might cause the nutrients level in the river water to increase. Moreover, without an efficient management of the waste disposal from the palm oil mills will increases the pollutant in the river. Untreated effluents from the mill will increase sedimentation in the rivers (Brown and Jacobson, 2005) where the effluents are acidic in nature and have high BOD and COD level (Brebbia and Katsifarakis, 2007). An increase in the sedimentation in the Chini River was caused by logging, agriculture, mining and water flow (Toriman *et al.*, 2009). Sediments are one of the possible media in aquatic

monitoring where it plays an important role in elemental cycling in aquatic environment. Sediments are also responsible for nutrients and pollutants entering water bodies besides water. In addition, the wastewater discharge from the residential area might contain some heavy metals that can be harmful to the species of aquaculture in the river.

Identifying the different types and sources of pollutant to the river are an essential way to manage the water quality. Not only identifying, to manage water quality it also involves monitoring and other investigations such as biological survey and chemical analysis (United Nations, 1998). Wastewater discharge along the river course might harm the quality of the river.

### 1.1 Problem Statements

On-going activities at the upper reaches of the Sampadi River are coal refinery, oil palm plantations and mill. These activities along the upper reaches river may affect water and sediment quality.

### 1.2 Objectives

The objectives of this proposed study was to determine the water and sediment quality at the upper reaches of the Sampadi River.

## 2.0 Literature Review

### 2.1 Characteristics of Rivers

In some rural area, a river plays an important role to the society. River is the source of water for people in that area and some people get their protein supply from it. River is also a place where some biological process as happen such as the exchange of respiratory gases of the aquaculture and for wastes removal during the process of low tide and high tide. This shows how important the rivers are to our daily life. In maintaining the quality of a river, both water and sediment need to be monitored. The characteristics of a river can be divided into two parts: water quality and sediment quality.

#### 2.1.1 Water Quality

Water is one of the important sources to examine the quality of a river. River is very sensitive and can easily be polluted by any sources especially the wastewater from the residential or industrial areas. Without proper monitoring and managing of the activities near the rivers, we might lose our rivers one day. Several analyses were done to ensure the quality level of the river.

##### 2.1.1.1 Five-day Biochemical Oxygen Demand ($BOD_5$)

$BOD_5$ shows the amount of oxygen that is used by the microorganisms in the river. $BOD_5$ also can be used to measure the pollution level of a river. The higher amount of $BOD_5$ the more polluted is the river. A research done by Yang *et al.* (2007) shows high $BOD_5$ values at Yangpu site, suggesting high organic matter input.

#### 2.1.1.2 Total Suspended Solids (TSS)

The amount TSS in the river can also be used to indicate the quality of the river water where the higher the amount of suspended solids, the more polluted is the river. This makes the river water unsuitable for drinking and aquatic life (Kanu and Achi, 2011). TSS can be in the form of fine sand or any tiny bodies that cause by soil erosion and been washed into the river. Yang *et al.* (2007) mentioned that during the rainy season, the suspended solid concentration would be lower than usual because the large amount of water input diluted in the river and this had shown in Wusong site of the Huangpu River where the dilution of tides at the estuary. Another research done by Ling *et al.* (2010a) at the residential areas and on-going construction work near the river can lead to a high TSS values which had exceeded 100 mg/L. The Brantas River in Indonesia showed high amount of suspended solids due to the sediment loads originating from volcanoes during the wet season and the domestic solid wastes (United Nations, 1998).

#### 2.1.1.3 Heavy Metals

There are many types of heavy metals that come from any sources such as the river suspended matters that releases metals and the wastewater that release from the residential or industrial area. Heavy metal is a toxic compound that can make the river water seriously polluted. The traceable or not traceable heavy metals in the river water, can also be observe in the sediments. A research done at the western part of Nigeria showed high concentrations of Pb, Ni, Cu, Zn and Cd due to the direct discharge of wastes by the butchery and some other indiscriminate wastes dumping into the stream (Ololade *et al.*, 2009). Eklip (2010) reported the decreasing sequence of heavy metals found in the water of the Sampadi River, Cr>Cu>Ni>Zn>Pb>Cd.

#### 2.1.1.4 Nutrients Analysis

Nutrients such as total nitrogen, $NO_3^-$-N, $NO_2^-$-N, $NH_3$-N, organic nitrogen, total phosphorus and reactive phosphorus can be found in the river water. The use of fertilizers and the water runoff from plantation area to the river might be the point of input of nutrients. More anthropogenic inputs of nutrients into the river led to more amount of microorganisms to decompose the wastes. As the amount of microorganisms increase in the river, the BOD value will tend to increase too (Yang *et al.*, 2007). Besides, high concentration of nutrients will also lead to algal blooms which can release toxic substances into the river water. High concentration of total nitrogen and total phosphorus lead to more eutrophication in the river (Dodds *et al.*, 1997) where Oberholster *et al.* (2008) reported >1500 µg/l of total nitrogen and >75 µg/l of total phosphorus in the catchment area of Lake Rietvlei. As for phosphorus, it is not only found in the fertilizers for plantation, but also can be found in the wastewater that contains detergent because phosphate is the basic compounds of detergent (Czemiel, 2000) that are mainly from the residential areas. Besides, urine and faeces also contains phosphate which may contribute to the concentration of reactive phosphorus and this was shown in the research at few residential areas in Kuching (Ling *et al.*, 2010b). The $NO_3^-$-N concentration is somehow related to the level of DO which nitrification process occurs from the oxidation of $NH_3$ to $NO_3^-$; *Nitrosomonas* bacteria will oxidize $NH_3$ to $NO_2^-$ and *Nitrobacter* will then oxidize $NO_2^-$ to $NO_3^-$ at the rock filter bed (Ling *et al.*, 2010b). At the Huangpu River, Yangpu site have the lowest $NO_3^-$-N values due to the low DO values because nitrification process needs the presence of nitrogen and oxygen in the water body (Yang *et al.*, 2007).

#### 2.1.1.5 Temperature

Temperature of a river depends on the altitude of the sampling sites and sampling seasons. According to Jonnalagadda and Mhere (2001), higher temperature was observed at three sampling sites due to the lower altitude and different sampling times.

#### 2.1.1.6 pH

pH test is one of the test to identify the alkalinity of a river. Based on Han *et al.* (2006), more alkaline water can make the dissolved heavy metals easier to adsorb on particles. The reason of a high pH value in the Santubong River is because of the anthropogenic inputs of nutrients into the river and that promotes algae growth and photosynthesis process (Ling *et al.*, 2010a). In the research at Huangpu River, Dianfeng site shows higher pH due to the cleaner water at the upper reaches of the river (Yang *et al.*, 2007).

#### 2.1.1.7 Salinity

This analysis is to determine the salt content in the river water. Salinity is originating from the saline rocks or happened because of the salt in the soil dissolves in the water and been washed to the river. Activities such as irrigation, deforestation and mining mobilizing salts naturally present in groundwater, can lead to a high salinity (United Nations, 1998). Based on Yang *et al.* (2007), the mixture of salt from the ocean with water and the tides makes salinity of Wusong site the highest.

#### 2.1.1.8 Turbidity & Transparency

Clarity of river water is very important to determine the cleanness of a river and its productivity. Large rivers are often very turbid, a fact that leads to low primary production; for this reason rivers are often heterotrophic where it is depending on the

import of ready-made organic matter (Giller and Malmqvist, 1998). Turbidity of river water is caused by the suspended particles such as organic matter, clay and any microorganism that make the water seem muddy or not clear. Based on the research done in Changshou Reservoir, transparency in the water body that cause by algal growth and soil erosion suspension was low which varied from 0.5 m to 1.55 m (Zhang *et al.*, 2006).

### 2.1.2 Sediment Quality

In order to confirm the quality of a river, sediment quality must also be monitored and tested. Sediments are natural occurring material that can be transported by the fluid flow due to the erosion and also weathering. Sediments and aquatic life are both related in the context that the quality of sediments are bad, it will affect the aquatic live and also their habitats. As mentioned by Calow & Petts (1992), the quality of sediments can affect the aquatic life directly by damaging their organisms plus habitats and indirectly by influence the turbidity and light penetration in the river. Sediment is a place where heaviest particles or matters settle down in the bottom.

#### 2.1.2.1 Particle Size

The flows of water in the river influence the particle size of sediments. Sediments can be in the form of sands, slits and clays. Particle size analysis (PSA) is a method used to measure the size distribution of particles in a soil sample and to evaluate the soil texture (Gee & Bauder, 1986).

#### 2.1.2.2 Organic Matter

Giller & Malmqvist (1998) indicate that there are 3 main types of organic matter that can be found in the rivers and streams. One of it is the coarse particulate organic matter (CPOM). CPOM is particles that are greater than 1 mm of size. Another type of

organic matter that can be found in the rivers is the fine particulate organic matter (FPOM). FPOM size of particle range from smaller than 1 mm down to 0.50 µm and it is primary generated from the breakdown of the larger CPOM. Most organic matter that passes the streams and rivers would pass through pore filter that size of 0.45 µm and this organic matter is called dissolved organic matter (DOM).

#### 2.1.2.3 Heavy Metals

Sediment is one of the inputs for contaminant so any types of heavy metals whether it is toxic or not, it will settle down in the sediments. How polluted is a river can be monitored by analysing the concentration of heavy metals in the sediments and identifing the types of metals present. Ozmen *et al.* (2004) reported that the order of the heavy metals and major elements in the sediments in decreasing concentration are Fe>Mg>Ca>Mn>Zn>Ni>Cr>Cu>Co>Pb in Hazar Lake. Meanwhile, Eklip (2010) reported the sequence of heavy metals found in the sediment of the Sampadi River as Ni>Cr>Pb>Zn>Cu>Cd.

#### 2.1.2.4 Total Phosphorus & Total Nitrogen

Both studies are identifying the nutrients level in the sediment. By analysing the total phosphorus and total nitrogen in the sediment, this can show the level of nutrients in the sediment.

## 2.2 Effects from the Land Use

### 2.2.1 Effects from the Oil Palm Mill and Plantation to the River

As mentioned in the introduction, when water runoff from the plantation area plus the use of pesticides, herbicides and fertilizers during the plantation, it can lead to high nutrients level in the river. Same goes to the palm oil mill, if the wastes or effluents from

the mill run directly to the river without a proper treatment, it will cause a huge environmental problem to the river plus the presence of the oil and grease which is not quickly broken down by the bacteria. The characteristics of this effluent are thick brownish liquid and it also has high values of BOD, COD, oil and grease (Ibrahim *et al.*, 2010). The value of oil and grease in the POME is 4000 mg $dm^{-3}$ which is a huge amount if compared to the regulatory discharge limits that is set by Malaysian Department of Environment which is 50 mg $dm^{-3}$ (Ahmad *et al.*, 2005).

In Pakistan, the use of agricultural chemicals leading to chemical pollution and when the residues are washed into the river has resulted in high nutrients level; for example pesticides that are of concern because their bioaccumulation in fish, animals tissue and soil (United Nations, 1998). From the previous study by Eklip (2010), it showed that the upper reaches of the Sampadi River received the input from oil palm mill (Sungai Chupin Besar station) and had a low temperature (28.4$^{o}$C), high salinity (16.50 PSU) and $BOD_5$ concentration during low tide (11.06 mg/L) and high tide (10.37 mg/L) for the water quality and high concentration of Cr in the sediments, while at the input from oil palm plantation, few water quality parameters tend to be the highest at that point such as transparency (56 cm), total phosphorus during low tide (2.85 mg/L) and concentration of TKN during low tide (30.58 mg/L) and high tide (22.54 mg/L). Besides, Ng (2009) had mentioned that the inputs from the factory or mill of the oil palm at the Sampadi River have the highest percentage of organic matter and nutrients.

### 2.2.2 Effects from the Residential Areas

Rivers are the easiest way for disposal of waste from some residential areas near the river. It is easy to contribute pollutants to the river but it takes a huge effort to make the river free from any pollution. Ling *et al.* (2009a) reported that greywater from a residential

area in Kuching City have a high $BOD_5$, COD and nutrients but low in DO before it undergoes biofilters treatment. This means wastewater from the residential areas will indirectly gives effects to the quality of a river. There are few sources such as washing, bathing, septic tanks and much more activities in the residential area that flows their wastewater into the river will somehow disturbed the quality level in that particular river. Mostly if from the sources that mention before, all that sources contribute to a high level of nutrients which could result in algal bloom and eutrophication.

Wastewater from the residential also contributed oil and grease from cooking and washing to the river system. It is a type of hazardous waste that must be treated and not simply runs into the river. For example the pollution in Bangladesh, most municipal sewage is discharged without treated and this caused high BOD level, DO depletion and high pathogen counts (United Nations, 1998). Solid wastes from the residential might contain heavy metals substances that will dissolve in the water or settle in the bottom of the river and mix with the sediment. There are many types of heavy metals which might become toxic to the river. Research at the Santubong River by Ling *et al.* (2010a) shows the highest $BOD_5$ (9.3 mg/L), TSS (134.9 mg/L) and $NO_3^-$-N (0.51 mg/L) values near the residential site which cause by the overflow from septic tank.

## 2.3 Effluent Discharge Standard

With the availability of the water quality standard and sediment guidelines, it can improve the management of a river and maintain its quality for future generation. The Water Quality Standard (Appendix A) is taken from the standard in Malaysia while Sediment Quality Guidelines for Metals and Nutrients (Appendix B) is taken from the guidelines in Ontario, Canada. This standard and guidelines can be used to compare the results that were done in this research.

## 2.4 Summary of Literature Review

In conclusion, it is important to monitor and analyse the quality of a river especially those that have higher possibility to get polluted by the activities near the river. As in the upper reaches of the Sampadi River, the activities of oil palm plantations could contribute pollution to the aquatic environment where polluted river will have high $BOD_5$ concentration, TSS, heavy metals and nutrients level in the water and sediment of the river. A few projects had been implemented in the watershed of this river but only few stations had been monitored and some of the test had not been done such as oils and greases and some nutrients analysis. In this project, the oils and greases in the river water was analysed plus to others parameters that had been done before.

## 3.0 Materials and Methods

### 3.1 Study Area and Sample Collection

The study took place at the upper reaches of the Sampadi River, Jalan Lundu, Sarawak (Figure 1). It is far away from the river mouth and that area consists of villages, oil palm plantations, an oil palm processing mill and coal refinery. Station S1 was located at the downstream which 0.5 km from the Temedak River, Station S2 was located in the Chupin Besar River which have an oil palm mill at the upstream area, Station S3 was located in between the Chupin Besar River and the Chupin Kechil River, Station S4 was located in Chupin Kechil River and Station S5 was located at the junction to Hujan River. There are oil palm plantations going on from Chupin Besar areas up to Chupin Kechil areas.

At each sampling location, water samples was collected from the river using 1.2 L polyethylene bottles and immediately placed in a cool box. The sediment was collected using plastic scoop from intertidal areas during low tide and immediately placed it into the cool box before transported to laboratory for analysis. There are two sampling trips with different tide flows as stated in Table 1.

**Table 1 Sampling dates and details.**

| Date | Time Range for Sample Collection (hours) | Tidal Conditions | Weather Conditions |
|---|---|---|---|
| 28 October 2011 | 1315 – 1420 | High tide (from downstream to upstream) | Sunny day |
| 10 February 2012 | 0935 – 1052 | Low tide (from upstream to downstream) | It was raining few days before and on the sampling day. |

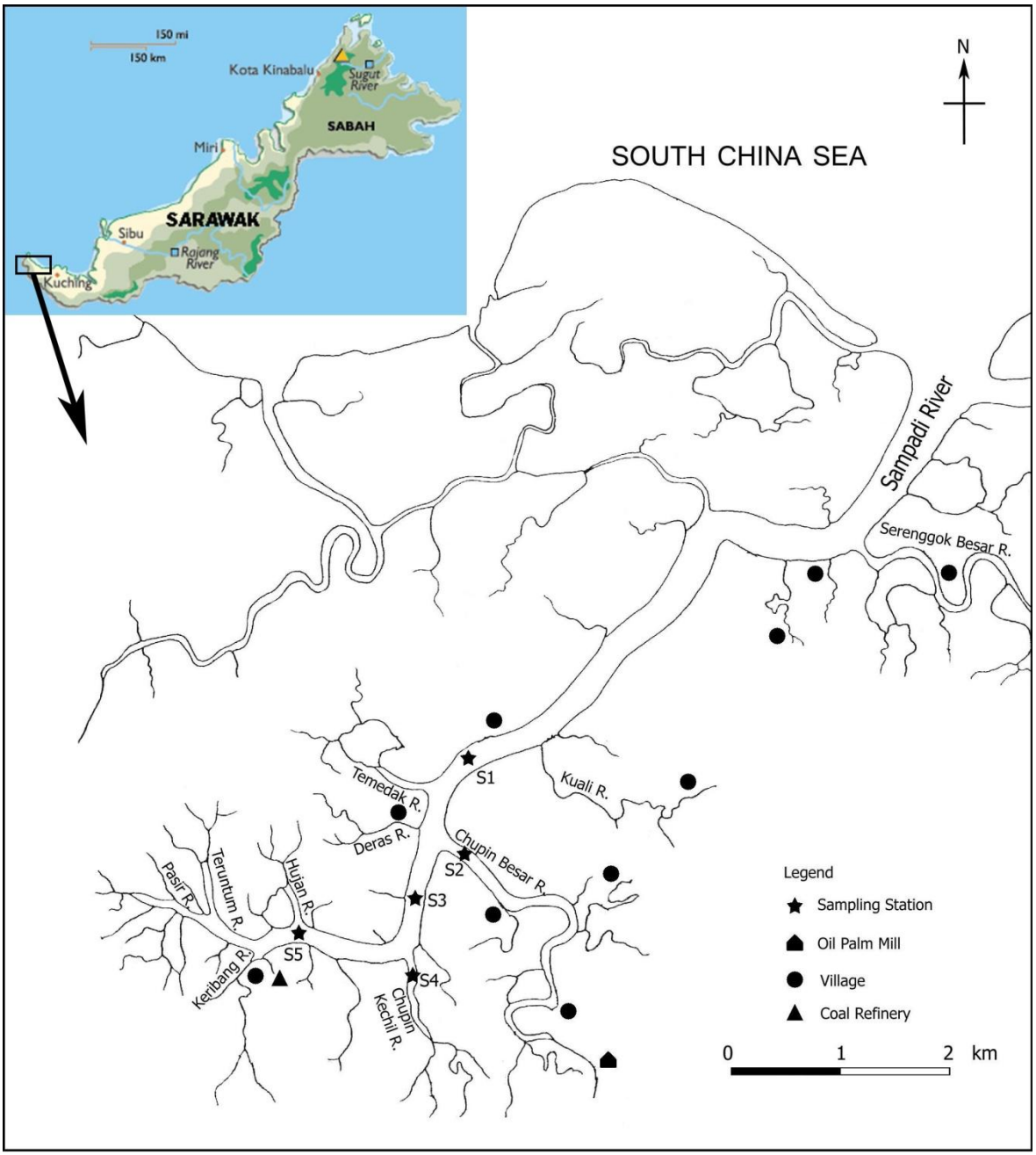


**Figure 1 Map of the Sampadi River showing the sampling stations.**