EFFECT OF LAND USE AND LAND COVER (LULC) AND ANTHROPOGENIC ACTIVITIES ON KINTA RIVER WATER QUALITY

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By

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LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
APHA	American Public Health and Association
BOD	Biological oxygen demand
COD	Chemical oxygen demand
DID	Drainage and Irrigation Department
DO	Dissolved oxygen
DOE	Department of Environment
EQA	Environmental Quality Act
GIS	Geographic information system
IRBM	Integrated River Basin Management
IWRM	Integrated water resources management
Kg.	Kampung
LULC	Land use and land cover
NWQS	National Water Quality Standards for Malaysia
SME	Small and medium enterprise
SS	Suspended solids
STSs	Sewerage treatment systems
TDS	Total dissolved solids
Tg.	Tanjung
USEPA	United States Environmental Protection Agency
WHO	World Health Organization
WQI	Water Quality Index
WQMP	Water Quality Management Plan

LIST OF SYMBOLS

°C	Degree Celcius
μg/L	Micrograms per liter
μS/cm	Micro Siemens/cm
mg/L	Milligram per liter
NO_3^-	Nitrate ion
NTUs	Nephelometric turbidity units
ppt	Parts per thousand
PO_4^{3-}	Phosphate ion
R^2	Adjusted R- Square
r	Correlation coefficient

LIST OF PUBLICATIONS

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Azyana Yaakub and Nik Norulaini Nik Ab Rahman. Assessing the Combination of WQI and NWQS of Kinta River Based on Land Use and Land Cover. 2011 School of Distance Education Postgraduate Colloquium, 19-21 November 2011.

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KESAN PENGGUNAAN TANAH DAN AKTIVITI ANTROPOGENIK TERHADAP KUALITI AIR SUNGAI KINTA

ABSTRAK

Penyelidikan telah dijalankan untuk menilai hubungan antara guna tanah dan kualiti air di Sungai Kinta. Objektif kajian ini adalah untuk mengenal pasti punca pencemaran yang mungkin mempengaruhi kualiti air, untuk menentukan pengaruh pengunaan tanah dalam zon jejari tertentu dan kawasan tadahan keseluruhan ke atas kualiti air sungai dan akhirnya untuk menyiasat penunjuk guna tanah yang terbaik bagi ramalan kualiti air sungai. 60 lokasi yang telah dikenalpasti sebagai sumber pencemaran yang berpotensi telah dianalisis dengan menggunakan kaedah ANOVA sehala. Mereka terdiri daripada pelbagai aktiviti antropogenik seperti perindustrian, kawasan perumahan, pasar basah dan sebagainya. Sepuluh lokasi (PT 1 hingga PT 10) terletak di anak Sungai Pari telah dipilih dan 90 sampel diperolehi dengan menggunakan kaedah persampelan *grab*. Peratusan guna tanah pemboleh ubah penentu/peramal khususnya tanah hutan, tanah pertanian, kawasan membangun, kawasan lombong dan jasad air telah diekstrak daripada kawasan tadahan keseluruhan dan zon penampan menggunakan data pemprosesan Arc View 9.3. Analisis statistik telah dijalankan terhadap 12 parameter kualiti air iaitu suhu, oksigen terlarut (DO), konduktiviti, kemasinan, jumlah pepejal terlarut (TDS), pH, permintaan oksigen kimia (COD), kekeruhan, nitrat, fosfat, permintaan oksigen biokimia (BOD) dan pepejal terampai (SS). Jelasnya, kawasan perindustrian mencatatkan purata bacaan tertinggi mana-mana satu daripada 12 parameter. Zon Perindustrian Bukit Merah mencatatkan suhu tertinggi 38.93 °C, Zon Perindustrian

Tasek tertinggi dalam kealkalian pada pH 9.04, Zon Perindustrian Bukit Merah (2) mencatatkan bacaan tertinggi dalam kekonduksian (31867 μS/cm), kemasinan (19.97 ppt) dan TDS (15920 mg/L), Zon Perindustrian Lahat/Rima mencatatkan COD (6263.00 mg/L) dan kekeruhan (373.20 NTU), Zon Perindustrian Jelapang dengan nitrat (84.37 mg/L) dan fosfat (251.67 mg/L). Manakala pembinaan Taman Wing Onn dan Restoran Kampar mencatatkan nilai tertinggi dalam SS dan BOD iaitu 962.67 mg/L dan 1395.67 mg/L dengan bacaan masing-masing. Landskap keseluruhan mempunyai pengaruh yang sedikit lebih besar ke atas kualiti air dan bukannya tapak persampelan jejari penampan tertentu yang telah ditetapkan. Jenis guna tanah membangun menjadi penunjuk terbaik dalam meramalkan kemerosotan kualiti air. Manakala tanah hutan, tanah pertanian, jasad air dan kawasan lombong tidak banyak menyumbangkan kepada pencemaran sungai. Kesimpulannya, kualiti Sungai Kinta adalah dipengaruhi oleh guna tanah dan aktiviti antropogenik di sekitar sungai.

EFFECT OF LAND USE AND LAND COVER (LULC) AND ANTHROPOGENIC ACTIVITIES ON KINTA RIVER WATER QUALITY

ABSTRACT

Research was carried out to assess the relationship between land use and water quality of Kinta River. The objectives of this research were to identify the possible pollution sources influencing the water quality, to determine the influence of land use and cover within zones of specific radii and entire catchment area on river water quality and to investigate the best land use predictor for the prediction of river water quality. Sixty locations were identified across the Kinta catchment area as possible pollution sources and had been analyzed with one-way ANOVA. These 60 locations were related to various anthropogenic activities such as industries, residential areas, wet markets etc. Ten sampling points (PT 1 to PT 10) of Pari River tributaries were selected and 90 water samples were taken from these points using grab water sampling method. The percentage of land use of five predictor variables specifically forest land, agricultural land, developed area, mining area and water bodies were extracted from the entire catchment area and buffer zone using Arc View 9.3 Data Processing. Statistical analysis was conducted against 12 water quality parameters; temperature, dissolved oxygen (DO), conductivity, salinity, total dissolved solids (TDS), pH, chemical oxygen demand (COD), turbidity, nitrate, phosphate, biochemical oxygen demand (BOD) and suspended solids (SS). It was obvious that the industrial areas recorded on the average the highest levels of any one of the 12 parameters. The industrial area of Bukit Merah Industrial Zone with highest temperature recorded at 38.93 °C, Tasek Industrial Zone was highest in alkalinity at pH 9.04, Bukit Merah (2) Industrial Zone had highest readings in conductivity (31867 μS/cm), salinity (19.97 ppt) and TDS (15920 mg/L), Lahat/Rima Industrial Zone recorded highest COD (6263 mg/L) and turbidity (373.20 NTU) and Jelapang Industrial Zone was highest in nitrate (84.37 mg/L) and phosphate (251.67 mg/L). While Taman Wing Onn construction site and Kampar River restaurants recorded highest levels in SS and BOD levels which were 962.67 mg/L and 1395.67 mg/L respectively. The entire catchment landscape appear to have slightly greater influence on water quality rather than the specific sampling site of predetermined buffer radii and developed land use becomes the best indicator to predict the degradation of water quality. Land use and land cover of forested land, agricultural land, mining areas and other water bodies do not contribute much to the river pollution. In conclusion, Kinta River water quality was influenced by land use and anthropogenic activities around the river.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Water is an undeniable significant element for life. Unfortunately, notwithstanding the fact that there is 3% of freshwater out of total water on earth, only a small percentage (0.01%) of this proportion is available for human use (Hinrichsen and Tacio, 2002). However, this small proportion is under immense stress and recently many regions and countries are recognized to have suffered similar and common problem, which is water pollution (Howarth et al., 2002; Chen et al., 2006).

The sustainable development of the entire biophysical environment depends on the river systems especially inland rivers flow through landscapes where "human nature" interactions have strong and long-lasting effects (Kowalkowski et al., 2006). From the study done, it is learnt that the land use patterns and human activities are the major factors to contribute a great influence on water quality (Ribbe et al., 2008; Zhang et al., 2009).

Multiple land use activities, including its point sources and non-point sources pollution influence the water quality leading to its degradation. According to the Department of Environment (DOE) report in 2006, the greatest water pollution sources were from sewage treatment systems, STSs (47.79%), followed by manufacturing industries (45.07%), animal farms (4.58%) and agro-based industries (2.55%). Point source pollution can be easily identified such as wastewater from discharged outlet from industrial wastewater and domestic sewage in urban areas that mainly affect the river water quality from nutrient and organic-chemical pollutants (Wang et al., 2007). While non-point source pollutions, include urban land use, agricultural practices and transportation infrastructures (Liu et al., 2009; Ribolzi et al., 2011). In agricultural catchment area, river water quality is mainly impacted by nutrients from farming systems which cause eutrophication (Borbor-Cordova et al., 2006).

However, it is proven from several studies that the water quality is at a good level in undisturbed regions or at any regions which is free from human activities (Ometo et al., 2000; Swaine et al., 2006). As a result, forested land is very closely connected to clean/good river water in watershed all around the world (Schoonover et al., 2005; Sliva and Williams, 2001; Woli et al., 2004).

In order to ensure the improvement of water quality of rivers and groundwater as well as to minimize the number of polluted rivers, Malaysia has launched the program of integrated water resources management (IWRM) and integrated river basin management (IRBM) (EPU, 2006; Mokhtar, 2003; Mokhtar, et al., 2001).

One of the major moves as a result of IWRM and IRBM is that there are now more centralized STSs constructed and all the public sewerage systems have been upgraded to ensure reduction in the untreated wastewater discharged into rivers. According to Paerl et al. (2004), the most effective way to control river water pollution is to have the management/planning at the catchment level. It is very important to identify the difference between the relationship of river water pollution and anthropogenic influences at a watershed scale in establishing an efficient watershed management system (Dowd et al., 2008).

Generally, different types of catchments which consist of diversified land covers and human activities form a larger watershed (Edwards et al., 2000; Shrestha and Kazama, 2007). In reducing non-point pollutant loads to streams, the watershed restoration activity had focused on the installation of riparian buffers (Dosskey et al., 2005; Hassett et al., 2005). The importance of the watershed management and the catchment scale studies is undeniable in determining the impact of human development on water quality, either for the watershed and or for the receiving waters.

However, notwithstanding the fact that many studies have been done, there are still unfinished and ongoing issues disputed among researchers as to whether the land use of the entire catchment area or that of the riparian zone which gave more impact to water quality whilst, all the other factors are constant (Osborne and Wiley, 1988; Delong and Brusven, 1991). There are two main reasons contributing to these uncertainties, firstly each catchment has a unique combination of characteristics which influence water quality and secondly, if thorough investigation is conducted, it will always lead to the extreme time and resource consuming. Some findings claimed that land use near the streams and rivers is the best water quality predictor compared to the land use over the entire catchment area (Osborne and Wiley, 1988; Hunsaker and Levine, 1995).

The relationship between water quality parameters and land use activities can be ascertained by numerous methods. A few studies have applied the Pearson's correlation as a measure of the strength of the connection between any two variables (Wang and Yin, 1997; Tong and Chen, 2002; Lee et al., 2009; Xiao and Ji, 2007). Some studies have applied simple correlation between pairs of parameters with the correlation condition measured according to R^2 (Gasim et al., 2006; Rhodes et al., 2001), while some have utilized the single linear model (Mattikalli and Richards, 1996; Xiao and Ji, 2007), the multiple linear regression model (Ferguson et al., 1996; Bahar et al., 2008; Sliva and Williams, 2001) and the nonparametric statistical analysis techniques (Liu et al., 2009).

1.2 Problem Statement

The importance of Kinta River as one of the water sources in Perak urges on the need for the protection of the quality and quantity of its water. The river is also considered as one of the significant tourist attractions among other heritages in this country. Previously, this river was the top picnicking and recreational spots for the public who lived within the 100 m range of the river. However, due to the human and industrial pollutants, the quality of its water is deteriorated and now has been classified under Class III, which is only suitable to be used for irrigation purpose, under the classification of National Water Quality Standard (NWQS).

Kinta River has been selected by Perak Drainage and Irrigation Department (DID Perak) as a part of ‘1 State 1 River’ since 2005. Currently, it is classified under average Class III of National Water Quality Standards for Malaysia (NWQS) with a water quality index (WQI) of 51.9 to 76.5.

For the past few years, the land use and land cover in Perak had experienced some changes and many have caused to the degradation of the Kinta River water quality. Thus, research on the relationship between the land use and its effects on the water quality of Kinta River is significant to ascertain the potential sources of pollution affecting Kinta River. Industrial discharge, improper sewage treatment, residential discharges, wet markets, animal husbandry, sand mining, land development and soil erosion may be the major (main) causes of pollution.

Water plays an important role as a medium to disperse toxic, chemicals and heavy metals to the ecosystems. Human health depends on the water quality management, hence there is need to enhance the existing water quality for human daily intake to minimize the health hazards (Biswas, 1981).

Polluted water have diminished function spawning health hazard to humans if consumed, harming aquatic life, release of awful odours, visual intrusion and economic cost to the government. Money spent to revive or remedy a polluted river can be very substantial.

1.3 Objective of Study

The review and initial survey on the area calls for a study to be conducted as aforementioned. Through investigation conducted with literature survey on similar work done elsewhere, led to the formulation of the following objectives:

1) To identify the possible pollution sources affecting the water quality of Kinta River;

2) To determine the effect of land use and cover (LULC) within zones of specific radii and entire catchment on river water quality;

3) To determine the best land use predictor for the prediction of river water quality degradation.

CHAPTER 2

LITERATURE REVIEW

There are many catchment areas in Malaysia now under pressure from urban, industrial and development of high class of infrastructures since we are moving towards 2020 Vision. As a result, the downstream receiving water bodies such as lakes, rivers, ponds, reservoirs, estuary and costal waters have become more and more sensitive where it's rates and volumes of runoff increased and the same goes to the pollutant discharged to the water bodies. Many urban and residential areas especially in the Western States of Peninsular Malaysia like Perak Darul Ridzuan are experiencing the effects of these problems. The problems get worst when there are frequent intense rainfalls, the physiological characteristics of the basin as well as the pattern of urbanization are very bad in urban areas (DID, 1994).

2.1 Development and River Management

No doubt, the economy growth of the country depends on both sectors of manufacturing and construction. The ongoing development has a great impact on the environment and the same goes to rivers, which have not been spared from such impacts of this development. The common issues related to rivers are:

a) Water shortage- It occurs when there is a rapid economic development and drought especially at regions with higher population growth; which is not parallel to what the river basin can support;
b) Flooding- Apart from natural flooding, flood due to the economic development that is flash flood also occurred mainly in urban areas and along highways;
c) River and water pollution- Deterioration of river water quality is synonym with development and resulted in pollution from both point and non-point sources. The main sources contributing to the organic water pollution are domestic and industrial sewage, effluent from palm oil mills, rubber factories and animal husbandry. While mining operations, housing and road development, logging and clearing of forest are major causes of high concentration of suspended sediment in downstream stretches of rivers;
d) River sedimentation- Downstream rivers are characterized by heavy silt loads especially after rains and some studies reported that 90% of sediment load to rivers come from land cleared for construction;
e) Squatters- The presence of squatters are due to the improper/poor management and there were no proper sewerage and rubbish disposal facilities.

2.2 Water Quality Management in Malaysia

2.2.1 Legislation

The main purpose of having laws is to control the pollution as well as to prevent the pollution in the river or water body. The legislative system for water quality management in Malaysia, which mainly focused on water quality conservation, can be divided into three categories:

i) General: Environmental Quality Standards for Surface Water, Environmental Quality Act (1974) and Effluents Discharge Standards;

ii) Specific Area: Selangor Waters Management Authority Enactment (1999), Kedah Water Resources Enactment (2007), Sabah Conservation of the Environment Enactment, Sabah Water resources Enactment (1998), National Resources and Environment Ordinance Sarawak;

iii) Specific Sector: Peninsular Malaysia- Agriculture: Irrigation Areas Act (1953), Drainage Works Acts (1954); Forestry: National Forestry Act (1984); Control of River: Water Acts (1920), Reviewed (1989), River Rights Enactment of Perak, Kelantan River Traffic Enactment (1955), Pahang River Launches Enactment 6/49; Land Management: National Land Code (1965), Land Conservation Act (1960), Earthwork by laws; Domestic Water Supply: Water Services Industry Act; Local and Regional Planning: Town and Country Planning Act (1976); Fishery: Fisheries Act (1963). State of Sabah and Sarawak- Agriculture: Drainage and Irrigation, Sabah Ordinance 15/1956, Drainage Works Ordinance Sarawak (1966); Forestry: Sabah Forest Enactment (1965), Forest

Ordinance Sarawak, Cap126; Land Management: Sabah Land Ordinance (1930), Sarawak Land Code (1958); Domestic Water Supply: Water Services Industry Act; Mining: Mining Enactment (1960) Sabah, Mining Enactment (1949) Sarawak.

2.2.2 Prevention

"Prevention is better than cure" is a useful adage to be upheld. This approach will invariably require the removal of the sources and causes. Section 34A of the Environmental Quality Act 1974 states that it is mandatory to report the impact on the environment resulting from described activities.

2.2.3 Erosion and Siltation Control

Uncontrolled and rigorous land clearance activities and earthworks for construction purpose have increased and these activities led to soil erosion and dumping of sediments into the nearest river. Authorities like Drainage and Irrigation Department (DID) and Department of Environment (DOE) have come out with their control measures for the developers to comply on title "Erosion of Soil and Control Plan" and "Guidelines for Prevention and Control of Soil Erosion and Siltation" respectively.

2.2.4 Administration and Public Participation

Cooperation and involvement of all stakeholders in the entire project/programme are the key element to success and sustainability in the long term.

2.2.5 Finance

It is a critical resource where all the programmes would entail both direct and indirect costs and benefits. Finance instrument is very important to ensure that all the projects and programmes run smoothly.

2.3 Integrated River Basin Management (IRBM)

The water resource need to be managed in a sustainable manner in order to ascertain a sustainable development of human population since the water demand keep on rising due to the population growth in Malaysia. Changes in land use such as deforestation, agriculture, industrial and housing development have huge impact on water quality in river system. The water resources management will be facing a great difficulty due to the lack of integration and holistic approach usually with little participation of the public and other stakeholders apart from the government. IRBM was introduced as the solution for this problem, which treated water as a finite and vulnerable resource, water as an economic good and water governance should be based on a participatory approach involving all levels of stakeholders. IRBM in water planning and development was introduced in the Ninth Malaysia Plan (2006-2010) and National Physical Plan (2006-2020). The integration means integration within and between natural and human system. As a sub-set of IWRM, the IRBM deals with management at the basin level involving aspects like water allocation, pollution control, flood control, etc. (Clausen, 2000). It can be defined as the coordinated management of resources in natural environment (air, water, land, flora and fauna) based on river basin as a geographical unit/area with the objective of balancing man's needs with necessity of conserving resources to ensure sustainability (Keizrul, 2000).

2.3.1 Importance of IRBM Concept

Land use, economic activities, water resources, water supply, water pollution and aquatic life are interrelated with each other at the river basin. However, the traditional legal and administrative roles aligned with different sectors leads to the separate responsibilities for these matters. Nevertheless, our nature is functioning as an integrated entity not in a segregated way. Thus, it is necessary to establish a mechanism that can merge the coordination and seek for the cooperation from all the stakeholders as well as manage it in a holistic system. The seven key elements to a successful IRBM initiative are:

- A long-term vision for the river basin, agreed to by all the major stakeholders.
- Integration of policies, decisions and costs across sectoral interests such as industry, agriculture, urban development, navigation, fisheries management and conservation, including through poverty reduction strategies.

- Strategic decision-making at the river basin scale, which guides actions at sub-basin or local levels.
- Effective timing, taking advantage of opportunities as they arise while working within a strategic framework.
- Active participation by all relevant stakeholders in well-informed and transparent planning and decision-making.
- Adequate investment by governments, the private sector and civil society organizations in capacity for river basin planning and participation processes.
- A solid foundation of knowledge of the river basin and the natural and socio-economic forces that influence it.

2.3.2 River Basins

A river basin is like a huge bowl that consists of a river, its numerous tributaries and the surrounding landmass, which captures the water that flows in to the river. The river basin is a huge catchment area that encompasses all the catchments of a river. The term watershed is synonymous with catchment, but is mainly used for areas in the upper reaches. River basins are divided into separate catchments or sub-basins. Except for small coastal areas with no significant watercourses, the entire land area is part of a river basin. River basins are dynamic over space and time, and any single management intervention has implications for the system as a whole. River basin problems also involve the interaction of-or even competition between-administrative bodies that often overlap at various levels (states or regions, districts and sub-districts) and between sectors (various government ministries and agencies that deal with water issues, typically the ministries of water resources, agriculture and environment) (Barrows, 1998; Moss, 2004).

2.3.3 IRBM Planning

In IRBM concept, planning is the most important key element since it helps us to define environmental issues and considers the interests of various stakeholders. It is compulsory to have an overall guidance in IRBM plan to channel clear and specific actions that address water quantity and quality issues and land use matters. These plans must cover and integrate the full array of water concerns, such as resource use and flood mitigation, wastewater treatment and catchment protection and zoning. Short term as well as a long term planning is required to fulfill the entire objectives of IRBM.

2.4 General Information on Kinta Catchment Area

The study area is located in the central-eastern section of Kinta District, in the state of Perak, Peninsular Malaysia. Kinta catchment is approximately 2565.45 km^2. The catchment highlands rise to over 2000 m above sea level. The eastern part of the hilly area are covered by the forest, medium slopes are covered by different agricultural crops and the flat area covered by barren land and urban areas. The upstream consists of very steep slopes covered by primary jungle.

2.5 Hydrological and Topographical Characteristics

The annual rainfall in this catchment area is approximately 2500 mm and is well distributed throughout the year (DID, 1994). The highest rainfall occurs in the inter monsoon period that are between October to November and March to May. The topography of the catchment area consist of steep forest-covered mountains and hills in the north and east, progressively giving way to the expansive Kinta Valley to the south of Ipoh, most of which lies between the 10 m and 50 m contour (JICA, 1999).

The main function of Kinta River is mainly for water supply. Under the implementation of Lembaga Air Perak (LAP), Kinta River Dam is the only dam in Perak that is able to provide 639 million litres of water per day; expected to be able to meet water demand in the Kinta Valley until 2020. The Kinta River Catchment has its origin in the main range of Peninsular Malaysia in the Northern Cameron Highlands, at an elevation of over 2000 m. The main river follows a steep westerly course, initially in mountainous terrain. At the Tanjung Rambutan gauge site (elevation = 65 m), 25 km from it source, the Kinta River commands a catchment area of 246 km^2. The river will turn southward after Tanjung Rambutan to reach Ipoh city.

The Kinta River flow for approximately 100 km in length and it is located in the central-eastern section of Perak State. Kinta River lies between latitude: 4.1°, longitude: 101.0166667° .The major tributary of the Kinta River from the northwest is the Pari River (245 km^2) which joins at Ipoh (Figure 2.1). Below Ipoh, the Kinta River has a narrow western watershed divide to the Tumboh River (340 km^2) which joins the Kinta River at Kg. Gajah, 19 km from its outlet to the Perak River. Tributaries from the steeper eastern watershed include the Raia River (250 km^2), the Kampar River (430 km^2) which joins at Tanjung Tualang and finally the Chenderiang River which joins 10 km above the Tumboh or Kinta River confluence. After Tumboh River confluence the Kinta River follows a sluggish course through low-lying swampy land to reach the main Kinta River at Bandar where the river is close to sea level (DID, 1994).

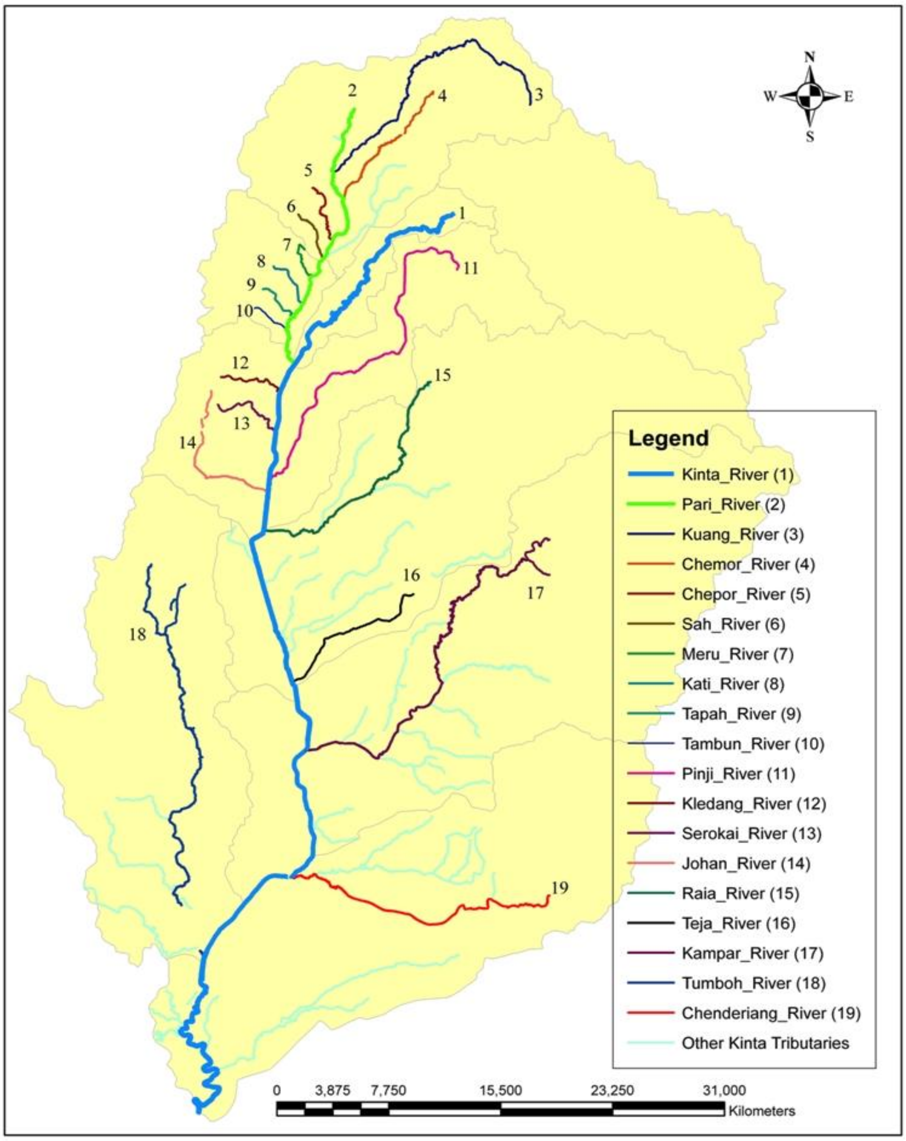

Figure 2.1: Map of Kinta River and its tributaries

Land use of the Kinta valley comprise of agriculture (e.g. rubber, oil palm and fruit trees), urban development and unproductive ex mining land, including tailings and ponds (Azamathulla et al., 2009). Kinta basin is rich with tin, mining activities and still re-mined since last century because it actually contribution to the economic development to this country. However, as we know, these kinds of activities had brought many problems to the environment. Large quantities of water, taken from the rivers for use in mining, have passed through tailings retention areas and discharged over spillways at limits progressively reduced over the years from 12 gm/litre to 3 gm/litre (DID, 1994).

2.6 Land use and Land Cover (LULC)

Land cover (LC) as defined by Barnsley et al. (2001) is "the physical materials on the surface of a given parcel of land (e.g. grass, concrete, tarmac, water)" and land use (LU) as "the human activity that takes place on, or makes use of that land (e.g. residential, commercial, industrial)". Changing land use and land management practices means altering the hydrological system, causing changes in runoff (Mander et al., 1998), surface water supply yields (Wu and Haith, 1993), as well as the quality of receiving water (Changnon and Demissie, 1996). Water quality is a measurement of the suitability of water for a particular used based on chemical, physical and biological parameters.

2.7 Land Use and River Hydrology

Many researches had been done on the impact of land use changes on hydrology (Choi et al., 2003; Aichele, 2005; Tang et al., 2005; White and Greer, 2006; Brandes et al., 2007) and reported there was a significant effect on land use changes, especially those caused by urbanization on hydrology.

2.8 Land Use and Water Quality

The relationship between land use and water quality and quantity is very complicated (Gburek and Folmar, 1999; Ngoye and Machiwa, 2004). However, many researches found that land use has a strong effect on water quality (Sliva and Williams, 2001; Woli et al., 2004; Schoonover et al., 2005; Tu et al., 2007). Urban or residential areas is a major factor which contributes to a great change in chemical water properties due to high concentration in several parameters tested (Tong, 1990; Wang and Yin, 1997; Sliva and Williams, 2001; Gasim et al., 2006; Bahar et al., 2008).

Forested land is a good water quality predictor that is functioning to decrease the level of inorganic ions and consequently reduces the water quality degradation (Sliva and Williams, 2001; Tong and Chen, 2002; Bahar et al., 2008). Agricultural activities including row crops, rangelands, in-season and off-season paddy farming, raising livestock and aquaculture. Bahar et al. (2008) and Tong and Chen (2002) found that farmland coverage has a high impact on the concentrations of both NO_3^- and SO_4^{2-} might be due to the fertilizers. Soil erosion and the resulting suspended sediment load affect water quality in agricultural areas (Mattikalli and Richards, 1996). Conversely, the study by Sliva and Williams (2001) found that agriculture is not a dominant indicator for degraded water quality.

Previous studies also proved that there were significant correlation between water quality parameters and land use types (Sliva and Williams, 2001; Woli et al., 2004; Mehaffey et al., 2005; Schoonover et al., 2005; Stutter et al., 2007). They found that the degradation of water quality is all caused by human activities including agricultural activities, forest management and industrial and residential wastes discharge. Unfortunately, the results of the relationship between land use and water quality parameters are found to be not consistent but different land use types are associated with different water pollution problems. For example, Tong and Chen (2002) examined the relationships of land use and water quality at Ohio State, USA. They found that total nitrogen, total phosphorus, conductivity and fecal coliform were significantly positively related to commercial, residential and agricultural lands but negatively related to forest land and BOD had a significant positive correlation with residential and commercial lands, a significant negative correlation with forest, but a non-significant correlation with agricultural land.

2.9 River Pollution

In Malaysia, major pollution comes from domestic wastes, industrial effluents and land clearance with suspended solids (SS) as the major contributor up of to 42% a poorly planned land development, 30% from biological oxygen demand (BOD) due of industrial waste and 28% from ammoniacal nitrogen (NH_3-NL) attributed to domestic sewage disposal and animal farming activities (Juahir et al., 2010). There are two types of pollution sources; point sources and non point sources (EPA, 1997).

2.9.1 Point Sources and Non-Point Sources

The types of pollutants and the ways water is used usually affect the quality of water resources. Point source pollution refers to contaminants that enter the water directly where the specific location at which the pollutant enters a stream can be identified. Point sources are easily identified and pollutant concentrations can be easily measured through in-situ and ex-situ methods (Malakahmad et al., 2008). Novotny and Chester (1981) stated that the characteristics of non-point source are, it happens in a short period, the pollutant enters the water through dispersed point, produced from activities that are continuous over a wide area and the point usually cannot be seen or is difficult to identify. Non-point sources are derived from activities on extensive units of land, originating from urban runoff, construction, hydrologic modification, mining, agriculture, irrigation return flows, solid waste disposal, atmospheric deposition, stream bank erosion and individual sewage disposal (Mogens, 1994). Table 2.1 shows sources of point and non-point chemical inputs according to Smith et al. (1999).

The concentration of pollutants carried in the runoff water may be lower compared to the concentration from point source. However, the total amount of pollutant delivered from non-point sources may be higher because it comes from multiple locations. It is very difficult to control as it come from many places and varies with time in terms of flow and the types of pollutants it contains.

Table 2.1: Sources of point and non-point chemical inputs Smith et al. (1999)

Point Sources
Wastewater effluent (municipal and industrial)
Runoff and leachate from waste disposal sites
Runoff and infiltration from animal feedlots
Runoff from mines, oil fields and unsewered industrial sites
Storm sewer outfalls from cities with populations > 100,000
Overflows of combined storm and sanitary sewers
Runoff from construction sites with an area > 2 ha
Non-point sources
Runoff from agriculture (including return flows from irrigated agriculture)
Runoff from pastures and rangelands
Urban runoff from unsewered areas and sewered areas with populations < 100,000
Septic tank leachate and runoff from failed septic systems
Runoff from construction sites with an area < 2 ha
Runoff from abandoned mines
Atmospheric deposition over a water surface
Activities on land that generate contaminants, such as logging, wetland conversion, construction and development of land or waterways

2.9.2 Livestock Farming

Wastes produced by a single swine, beef and dairy or poultry facility is almost the same to a small city. Researchers found that the cattle could produce a high amount of *Escherichia Coli, Cryptosporidium, Giardia* and other microbes (Oliver et al., 2005; Edwards et al., 1997; Doran and Linn, 1979). The agricultural wastes may become a source of pathogens to the groundwater, surface water and soil (Kay et al., 2008; Abu-Shour et al., 1994). Therefore, by spreading these wastes, human being and animal may be exposed to a high health risk if the wastes are not well treated as the animal manure contain pathogens (Jamieson et al., 2004).

2.9.3 Urban Areas

According to Eriksson et al. (2002) only 45% of the rivers are clean and the rest need to be rehabilitated to regain the clean status. Urban wastewater can be defined as a domestic wastewater or a mixture of domestic wastewater with the industrial wastewater and /or runoff rainwater. The most challenging part to improve the quality of water is dealing with the imprudent sullage discharge. Sullage or gray-water is defined as wastewater without any input from toilets (excreta) mainly originates from wet markets, kitchen sinks, bathrooms, washing machines, restaurants and car washing premises. Nonetheless, sewage has also taken up significance as one of the main reasons for river pollution in this country and some studies revealed that untreated sullage (DOE, 2004) and urban runoff (DOE, 2003) are responsible for the poor quality of water in our rivers.

2.9.4 Domestic Sewage

In Malaysia, domestic sewage currently contributes to almost half of the organic pollutant load in the aquatic environment. It has been reported that the main pollution source of the Sarawak River was discharges from households (NREB, 2001; Ling et al., 2006). Aside from the industries, sewage treatment sytems (STSs) are the most common type of point sources finding its way into the rivers. These two sources will discharge one or more pollutants within the wastewater called effluent into the river. In the worst situation, the factories will discharge their effluents directly to a water body without any treatments. The function of STS is to treat human waste to the regulated limit before being permitted to be released into any river. From 120 river basins monitored in 2001, 60 basins (50%) have thus far been clean, 47 (39%) were slightly polluted and 13 (11%) were polluted (DOE, 2002). Fifty one percent of the pollution in these basins were from domestic sewage facilities, 39% from manufacturing industries, 7% from pig farms and 3% from agro-based industries (DOE, 2002).

2.9.5 Industries

River, which is polluted by heavy metals and hazardous waste, which is discharged from upstream industrial areas, become the extreme kind of polluted river (Chan, 1999b). This indiscriminate pollution happens because of the poor attitude of the entire workers of the factories. Even though the privatization of treatment has been made, there are still a lot of factories that are not treating their wastes before discharging into water bodies and some have been caught for illegal dumping of wastes. Toxic illegal dumping and leakages of waste products from improper constructed containers as well as accidental spillages will harm the rivers and will no longer perform their self-purification function.

2.10 Environmental Quality Act 1974

The new regulations under the Environmental Quality Act 1974, namely Environmental Quality (Industrial Effluent) Regulations 2009 and Environmental Quality (Sewage) Regulations 2009, have been gazetted in December 2009.

2.10.1 Environmental Quality (Industrial Effluents) Regulations 2009

Fifth Schedule [Paragraph 11 (1) (a)]

Table 2.2: Acceptable conditions for discharge of industrial effluent or mixed effluent of Standards A and B

	Parameter (1)	Unit (2)	Standard A (3)	Standard B (4)
(i)	Temperature	^{o}C	40	40
(ii)	pH Value	-	6.0 - 9.0	5.5 - 9.0
(iii)	BOD_5 @ 20 ^{o}C	mg/L	20	50
(iv)	Suspended Solids	mg/L	50	100
(v)	Mercury	mg/L	0.005	0.05
(vi)	Cadmium	mg/L	0.01	0.02
(vii)	Chromium, Hexalent	mg/L	0.05	0.05
(viii)	Chromium, Trivalent	mg/L	0.20	1.0
(ix)	Arsenic	mg/L	0.05	0.10
(x)	Cyanide	mg/L	0.05	0.10
(xi)	Lead	mg/L	0.10	0.5
(xii)	Copper	mg/L	0.20	1.0
(xiii)	Manganese	mg/L	0.20	1.0
(xiv)	Nickel	mg/L	0.20	1.0
(xv)	Tin	mg/L	0.20	1.0
(xvi)	Zinc	mg/L	1.0	1.0
(xvii)	Boron	mg/L	1.0	4.0
(xviii)	Iron (Fe)	mg/L	1.0	5.0
(xix)	Silver	mg/L	0.1	1.0
(xx)	Aluminium	mg/L	10	15
(xxi)	Selenium	mg/L	0.02	0.5
(xxii)	Barium	mg/L	1.0	2.0
(xxiii)	Fluoride	mg/L	2.0	5.0
(xxiv)	Formaldehyde	mg/L	1.0	2.0
(xxv)	Phenol	mg/L	0.001	1
(xxvi)	Free Chlorine	mg/L	1	2