CHAPTER I

INTRODUCTION

1. General Introduction

Precipitation that does not evaporate or infiltrate into the ground runs off over the surface, drawn by the force of gravity back toward the sea. Rivulets accumulate to form streams, and streams join to form rivers. Rivers contain less than 0.01 percent of the Earth's surface water but originate in several possible sources. Most are fed by springs or small streams coming together to create larger rivers of water. Although the total amount of water contained at any time in rivers and streams are small compared to other water reservoirs of the world, these surface waters are vitally important to humans and most other organisms (Cech, 2003). Most rivers, if they were not constantly replenished by precipitation, melt-water snow and ice or seepage from ground water, would begin to diminish in a few weeks.

Rivers and their associated ecosystems and biological diversity provide life support for a high proportion of the world's population. Poor management of land and water resources in many river basins has led to major floods, water shortages, pollution and loss of biodiversity, worldwide. Restoration and rehabilitation of river catchments or water sheds has been identified for a number of years as an important strategy for both maintaining and improving river water quality as well as reducing flood peaks and maintaining dry season flows (Parish, 2003). The stimulus for restoration and rehabilitation of rivers has generally comes from deteriorating river water quality, increased level of floods and impacts on loss of ecosystems and biodiversity.

1.1 Water Quality Studies in Sungai Pencala

1.1.1 Background of the Study

Rivers that are subjected to anthropogenic influence are particularly susceptible to pollution inputs. Point source discharge, particularly sewage and industrial effluents, have significant detrimental impacts on the environmental quality of receiving waters. Hence, if the condition in the river is not closely monitored especially the changes in the spatial and temporal trends of key water quality parameters, then sudden problems may emerge (Gray, 1999).

Apart from the traditional role of drainage, river transportation and food resource, rivers also have great potential for recreations and tourism. In order to serve the above mentioned roles and functions, rivers need to be conserved and should remain clean and unpolluted. For example, the Sg. Langat in Selangor plays a significant role in ecology, provide potable water to residents, supply industries and agricultural areas with water for manufacturing and agricultural production, and provide other services such as recreational sites and habitats for fish and other aquatic wildlife (Nordin and Azrina, 1998). In India, the Ganga River has many beneficial uses such as bathing, swimming, public water supply, agriculture, industry, fish culture, wildlife boating and non-contact recreation (Devendra Swaroop hargava, 1983).

River is one of the most important natural resources. Due to the discharge of industrial waste, sewage discharge, agricultural activities, land clearing river gets polluted. Sungai Keladi in Kelantan as a DOE study found that human faeces, and not industrial waste, make up the bulk of organic pollutants in the heavily polluted rivers of the country. Drainage and Irrigation Department director-general Datuk Keizrul Abdullah said a study carried out by the Department of Environment two years ago showed that 91% of the organic pollution was caused by faecal matters. He said this occurred because many residents who used septic tanks refused to engage Indah Water Konsortium to carry out de-sludging periodically, by Sira Habibu (Bernama May 1, 2007). Sewage is the main cause of river pollution in the country and the public will have to live with it for about 30 years before the problem can be resolved, said Department of Environment (DOE) director-general Datuk Rosnani Ibrahim. She said two-thirds of rivers nationwide were polluted by sewage from households and business premises, (Dec 5 2006, The Star).

During recent years, serious concern has been voiced about the rapidly deteriorating state of freshwater bodies with respect to trace metal pollution. It is also reported that serious metal pollution could result from the discharge of unregulated effluents into the natural freshwater bodies. In Brazil, Veado (1997) pointed out those wastewaters from about 24 legal and several clandestine industries are discharged into the Das Velhas River. In spite of environmental controls carried out by multinational companies, pollution from smaller, sometimes clandestine, industry is still rife and this is the largest environmental problem. Earlier base-line studies have identified elevated levels of certain trace metals in freshwater systems around the world, especially rivers arising mainly from agricultural and industrial processes (Tariq et al., 1996).

There are so many cases, for example in April 1997, more than RM 100,000 worth of fish bred off Kukup, near Pontain died due to effluents flowing from nearby river. (The Professional Bulletin of the National Poison Centre, Malaysia, 1998) In October, more than 80,000 full grown fishes 70 farms at Kampung Teluk Jawa were destroyed due to toxic effluents from nearby factories. (The Professional Bulletin of the National Poison Centre, Malaysia, 1998).

Rivers in Malaysia have made immense contributions to the overall development of this country. They have provided power generation, water for domestic, agricultural and industrial consumption and have served as means of transportation and communication for the people. The towns and cities of Malaysia began as settlements along rivers while river mouths provided refuge and became homes to fisherman who braved the open seas to seek their living (Department of Irrigation and Drainage, 1992).

Many of the river systems in Asia have been degraded through pollution, over obstruction of water or clearance and degradation of catchments areas. Degradation of these river systems has had a significant negative impact on the local communities as well as the biodiversity. Recent experience has indicated that restoration of river ecosystem is possible but requires routine monitoring and careful management (Parish, 2003). The accurate and useful interpretation of data from a monitoring survey of river quality requires a relatively complete understanding of basic limnology. This will enable accurate and specific interpretation of data from a monitoring or survey undertaken. Restored river system can provide significant benefits such as improved water quality, reduced flooding, restoration of fishery and as well as protection of biodiversity.

1.1.2 Significance of the study

Measuring water quality of surface water is important in order to prevent health impacts to human being in particular and to other aquatic environment in general. There are water related diseases that could harm human health such as cholera, malaria and parasites and excess of harmful substances such fluoride, arsenic, metals and salt (Chacon-Torres et al. 2002). By measuring the water quality of the river, level or status of the surface water also can be defined whether it is clean, slightly polluted or polluted. These three types of water status will determine the suitability of the water to be used. There are many examples of the assessment of the water quality and ecology of Malaysian river system in the published literature. However, most of such studies have been conducted in the major river basins such as Klang River, Selangor River and Langat River. Water quality studies in the tributaries of major rivers are equally important to understand pollution loading pattern occurring into major rivers in Malaysia. It is hoped that the current study on the Pencala River will contribute to the body of knowledge of an urban river which is also one of the major tributaries of Klang River.

1.2 Bioaccumulations of Heavy Metals in Aquatic life in Sungai Pencala

1.2.1 Background of the study

Bioaccumulations or biological magnification is the bioaccumulation of a substance up the food chain by the transfer of residues of the substance in smaller organisms that are food for larger organisms in the chain (Sadiq, 1992; Salomon et al., 2005).It also refers to the ability of organisms to accumulate chemical from its surrounding by every means and route. It is a sequence of processes that result in higher concentrations in organisms at higher levels in the food chain. These processes result in an organism having higher concentrations of a substance than is present in the organism’s food. Bioaccumulations can result in higher concentrations of the substance than would be expected if water were the only exposure mechanism (Master et al., 1998).

1.2.2 Mechanism of Bioaccumulation

Bioaccumulation can only take place if the rate of uptake by the organism exceeds the rate of elimination (Spacie and Hamelink, 1985). Physiologically, adsorption mechanism is important in determining the affect of the chemistry of pollutants on bioaccumulations. Marine biotas that utilize gill tissues for active absorption of nutrients are affected by concentrations and the chemical forms of metals in the external medium. Bioaccumulations happen when the concentration of trace elements is higher in the river ecosystems. Lipid soluble (lipophilic) substances cannot be excreted in urine, a water-based medium, and so accumulate in fatty tissues of an organism if the organism lacks enzymes to degrade them. When eaten by another organism, fats are absorbed in the gut, carrying the substance, which then accumulates in the fats of the predator. Since at each level of the food chain there is a lot of energy loss, a predator must consume much prey, including all of their lipophilic substances (Mason, 1996).

There are five potential routes for a pollutant to enter a fish: via the food, non-food particles, gills, oral consumption of water and the skin. Once the pollutant is absorbed, it is transported by the blood either to a storage point (i.e. bone) or to the liver for transformation and/or storage. According to Salomon et al., (2005), if the pollutant is transformed by the liver it may be stored there or excreted in the bile or passed back into the blood for possible excretion by the gills or kidneys, or stored in fat, which is an extra-hepatic tissue. Therefore, the concentration found in different tissues, after environmental exposure, for a specific time, depends on several dynamic processes all taking place concurrently.

The concentrations of metals in aquatic organisms vary because they reflect the net effect of two competing process, that of uptake and of depuration. The balance between the two will depend upon the ambient water concentrations and the relative rates of the two processes. A number of factors, which may introduce a seasonal pattern of variation, also affect it (Mason, 1996; Mance, 1987). The ambient concentration of metal in the water will vary itself because of changes in the available dilution, in the rate of dispersion and in the rate of addition of metal.

1.2.3 Impact of Bioaccumulations of heavy metals on the river ecosystems

There are many impact brought by the bioaccumulation both to aquatic life and to water quality. In general, bioaccumulation of heavy metals in aquatic life can cause ecological impacts such as increasing of predation, mortality and reducing the reproduction rates and population. Bioaccumulation gives an adverse effect on fish health where it can lead to serious health problems such as cancer, lesions, developmental abnormalities, chronic diseases & disorder, genetic damage, sex changes, severe poisoning & death (The National Poison Center, Malaysia, 1998). Besides that, the transfer of some pollutants from mother to offspring during gestation/lactation, particularly in marine mammals will lead to infertility, birth defects, hormone disruption, behavioral changes, immune/nervous system disruption, kidney & liver damage (The National Poison Center, Malaysia, 1998).

An effect on the food chain occurs when bioaccumulation of heavy metals up the food chain autotrophs (i.e. plants and plankton) can passively absorb. While bioaccumulation heterotrophy actively absorb and biomagnify, predators consuming affected prey and will absorb the contaminants from the tissue, resulting in an even greater concentration of heavy metals in higher species and accumulation in some species has been known to reach levels of a million times greater than the concentration of heavy metals in the surrounding environment (Salomon *et al*., 2005).

A regular water quality monitoring survey encompassing appropriately selected sampling locations and the proper sampling and analysis of relevant water quality parameters is essential to regularly assess the status of a river system so that early signs of potential are identified. Examples of such pollutants include cyanide, zinc, lead, copper, cadmium and mercury (Salomon *et al*., 2005).

These substances may enter the water in such high concentrations that fish and other animals are killed immediately. Sometimes the pollutants enter a food chain and accumulate until they reach toxic levels, eventually killing birds, fish and mammals. In polluted areas, bioaccumulation by an organism can occur when the rate of uptake of a pollutant exceeds its rate of elimination. (Andersonand Brown., 1978) found higher concentrations of Cd and Pb in crayfish (Orconectes virifis) collected from a contaminated site than those from an uncontaminated site. Similarly, (Khan *et al*., 1989) reported higher concentrations of Cu, Hg, and Zn in grass shrimp (Palaemonetes pugio) collected from a polluted creek than those from a non-polluted creek.

However, many aquatic animals under contaminated conditions are able to maintain trace metal concentrations in the body at a normal level. McDermott *et al.* (1976) reported that Dover sole (Microstomus pacificus) collected from contaminated and uncontaminated sites accumulated comparable levels of silver, cadmium, chromium, copper, nickel, lead, and zinc. Studies on the bioaccumulation of pollutants by aquatic life are important in determining pollutant concentrations in aquatic life, tolerance limits of aquatic life species and effects of pollutant on aquatic life, and in assessing the water quality of the river in spatial and temporal, trends. Therefore it is important to carefully design the sampling strategy, analyses of data and statistical evaluation of the results in order to arrive at a successful monitoring program on bioaccumulations. These can be achieved by using simple and reliable sampling techniques and analytical methods capable of generating accurate and reproducible data on bioaccumulations of heavy metals in aquatic life in water bodies.

1.2.4 Significance of the Study

Numerous studies have been conducted to assess the extent of bioaccumulation of heavy metals in aquatic organisms. According to Nussey *et al.*, (2006), when fish are exposed to elevated metal levels in an aquatic environment, they can absorb the bioavailable metals directly from the environment *via* gills and skin or through the ingestion of contaminated water and food, thus accumulates heavy metals in their tissues. The heavy metals will then enter the food chains and extent to many other problems to human and to river eco systems itself. Beside that, other well known cases of bioaccumulations of heavy metal took place in 1938 when a Japanese factory discharged a significant amount of mercury into Minamata Bay. It took a decade for the problem to come to light. By that time, many local people had consumed the fish and around 20000 of people were poisoned. Hundreds of people were left dead and disabled (Ayres., 1977). The study of bioaccumulation in Malaysian rivers is lacking, therefore, there is a need to carry out the study of heavy metals Bioaccumulation in aquatic life in Malaysian rivers. In this study, species of fish and plant samples at 4 different locations of Sg Pencala were analyzed for bioaccumulation studies on certain heavy metals. It is hoped that these data will contribute to the beginning and extending the bioaccumulation study on other rivers in Malaysia.

1.3 Solid waste characterization Study in Sungai Pencala

1.3.1 Background

Solid waste comprise all the wastes arising from human and animal activities that are normally solid and that are discarded as useless or unwanted (Tchobanoglous, 1993).

Dumping of solid wastes on the banks of rivers has severely deteriorated the surface and subsurface water quality. Solid wastes could affect the water quality in terms of their biological, physical and chemical parameters. In the presence of solid wastes in river bodies, the COD and BOD tend to be higher due to the leaching of organic materials from the solid wastes (Yusoff, 1997). Solid wastes such as food waste, hazardous waste and plastic waste contains chemicals. These chemicals will leach off to the water and result in high COD value.

Nitrogen exists in various forms in water including nitrates, nitrites and ammonium. Solid wastes may have significance impact on these different forms of nitrogen. Solid wastes from the constructional site (rocks, timber, and concrete waste) can have a direct impact on the water turbidity and also result in higher conductivity values (Devkota and Watanabe, 2004). It is important to make sure that the rivers are clean and free from solid wastes and other pollutant so that the value of the river can be protected for its intended use.

1.3.2 Significance of the Study

Solid waste is one of the major contributors leading to the pollution problem. Pollution and degradation of these river systems has had a significant negative impact on the local communities as well as biodiversity. Preventive action can be taken if we can identify the sources of solid waste generation. Without the proper and well planned prevention programs, it is impossible to see Sungai Pencala to be free from solid waste.

If we know the major types of solid waste present in Sungai Pencala, preventive action could be taken to reduce the amount of solid waste at their sources. To prevent and solve the water pollution problems it is necessary to monitor the present level of the load of solid waste which requires careful characterization of the solid waste load with proper monitoring techniques. From these data, mitigation measures could be taken to conserve the quality of the river by the Government or NGO's. These survey data are very important as it plays an important role to create awareness on the adverse impact on the environment in terms of pollution prevention, river rehabilitation and restoration works and to improve the river water quality to achieve a clean condition.

Studies conducted on solid waste characterization of rivers in Malaysia are much lacking. It is hoped that the current study on solid waste characterization in Sungai Pencala will contribute to the knowledge on the impact of solid waste on an urban river which is also one of the major tributaries of the Klang River.

1.4 Research Objective

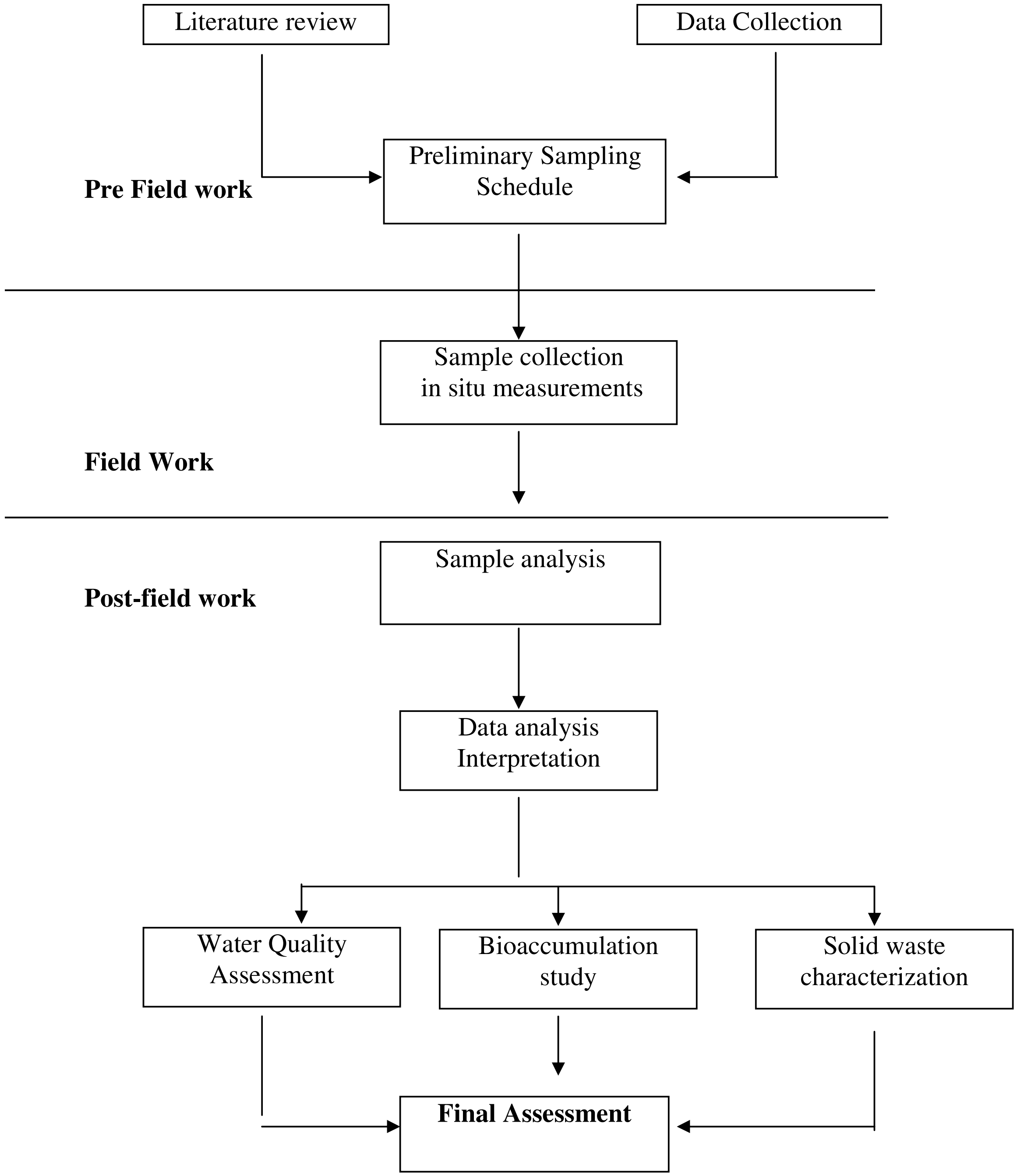
To prevent and solve the water environmental problems we need to monitor the present level of the pollutants load which requires identification of the pollutants load and monitoring techniques. In order to take effective control measures and implementation of pollution preventing activities water quality data, bioaccumulations data and solid waste data are required. Based on the data produced from Effective River monitoring survey, mitigation measures could be taken to conserve the quality of the river by the Government. These survey data are very important as it plays an important role to create awareness on the adverse impact on the environment to the public. These data are also important for projects related to pollution prevention, river rehabilitation and restoration works.

In view of the above-mentioned facts, the present study is undertaken

- To analyse the key water quality parameters of Pencala River from upstream at Bukit Kiara to down stream, at Petaling Jaya Old Town.
- To use the water quality monitoring data to calculate Water Quality Index of Sungai Pencala.
- To analyse selected heavy metals bioaccumulation in aquatic organisms in selected locations
- To characterize solid waste pollution in Sungai Pencala in selected locations along Sungai Pencala

It is hoped that the outcome of the study will assist in the implementation of water pollution control and management strategies hence improve the quality of Malaysian rivers and the status of its biodiversity.

Fig 1.1 Flow chart of the study



CHAPTER II

LITERATURE REVIEW

2.0 Literature Review

2.1. Water Quality Studies

Water Quality is the chemical, physical and biological characteristics of water that characterizes through the methods of hydrometry (Chacon -Torres et al. 2002). The primary bases for such characterization are parameters that relate to drinking water. Water quality shows whether the water is polluted or not. Water quality in general depends on factors and inputs not only from man-made sources, but also due to natural causes such as geologic formations, vegetation, geographic factors, natural eutrophication etc. Water chemistry is often used as a measure of aquatic ecosystem health. A single water quality sample, however, provides a snapshot of conditions of a single moment. Trend analysis of data collected over a long period of time is necessary to understand factors operating on a watershed-wide scale (Smith, 2004).

Water quality data are collected based on *in-situ* measurements and laboratory analyses. The most common parameters measured are those related to water pollution due to land clearing, sewage and effluents discharge. The water quality of the rivers discharging into a lake is the main determining factor of the water quality status of the lake. The locations of the outlets of the rivers into a lake together with morphological and hydraulic factors determine the spatial distribution of the problem, (Chacon -Torres *et al.* 2002). The approach to water quality standards is primarily based on existing chemical water quality such as DO, COD BOD, NH_3-H , trace Metals and selected organic constituents (Norhayati, 1997)

2.1.1 Biochemical Oxygen Demand

Biochemical oxygen demand, or BOD, measures the amount of oxygen consumed by microorganisms in decomposing organic matter in stream water. This test is used to measure the amount of oxygen consumed by these organisms during a specified period of time (usually 5 days at 20^{o} C). The rate of oxygen consumption in a stream is affected by a number of variables: temperature, pH, the presence of certain kinds of microorganisms, and the type of organic and inorganic material in the water. BOD directly affects the amount of dissolved oxygen in rivers and streams. The greater the BOD, the more rapidly oxygen is depleted in the stream. This means less oxygen is available to higher forms of aquatic life (Chapman, 1996). The consequences of high BOD are the same as those for low dissolved oxygen: aquatic organisms become stressed, suffocate, and die. Sources of BOD include leaves and woody debris; dead plants and animals; animal manure; effluents from pulp and paper mills, wastewater treatment plants, feedlots, and food-processing plants; failing septic systems; and urban storm water runoff (EPA, 1997). BOD is therefore the major criteria used in stream pollution control where organic loading must be restricted to maintain desired dissolved-oxygen levels. It is used for checking the quality of effluents discharged to such water. The higher the BOD value, the greater number of microorganism in water (Spooner, 1985).

2.1.2 Nutrients

Nitrogen is required by all organisms for the basic processes of life to make proteins, to grow and to reproduce. Nitrogen is found in many forms in the environment. Inorganic forms include nitrate (NO_3^-), nitrite (NO_2^-) ammonia (NH_3) and nitrogen gas (N_2).

Organic nitrogen is found in the cells of living things. Excessive concentrations of nitrate and nitrite can be harmful to humans and wildlife. Nitrate is broken down in the intestines to become nitrite resulting in blue baby syndrome that limits the ability of red cells to carry oxygen. It can also cause brown blood disease in fish. The sources of the nitrogen into the water include wastewater and septic system effluent, fertilizer runoff, animal waste, fossil fuels and also industrial discharge (Tilton, 1979). Nitrogen uptake is most effective when water flows slowly and evenly over the wetland surface thus providing an increase in the effective area and detention time available for biological interactions (Simpson, 1980; Tilton, 1979). During high flow conditions, elevated nutrient levels in outflow waters have been reported and have been attributed to leaching and flushing of decomposing plant material (Ziemer, 2003).

Nitrification refers to the biological conversion of ammonium compounds to nitrite and nitrate-nitrogen by bacteria in the presence of oxygen where approximately 4.6 mg/l of dissolved oxygen is required to convert 1 mg/l of nitrogen (USEPA, 1975). Minimum nitrification occurs when dissolved oxygen is less than 2 mg/l (O, 1974). The bacteria, specifically Nitrosomonas and Nitrobacter, are dependent upon aquatic vegetation for appropriate habitat while the aquatic plants utilize the nitrates produced by the nitrifying bacteria. The nitrate produced during this process will either be taken up by plant roots or diffused into the anaerobic zone where denitrification proceeds (Berding et al 2000).

Phosphorous exist in water in either particulate phase or dissolve phase. Particulate matter includes living and dead plankton. Dissolved phase includes organic and inorganic phosphate. Phosphates are not toxic to people or animals unless they are present at very high levels. In freshwater lakes and rivers, phosphorus is often found to be the growth-limiting nutrient because it occurs in the least amount relative to the needs of plants (Spooner, 1985). If the excessive amounts of phosphorus and nitrogen are added to water, algae and aquatic plants can be produced in large quantities. This process is called eutrophication. When algae die, bacteria decomposes them and use up oxygen. Dissolved oxygen concentrations can drop too low for fish to breathe, leading to fish dying. The loss of oxygen in the bottom water can free phosphorus previously trapped in the sediments, thus increasing the available phosphorus (Chapman 1996).

2.1.3 Microbiological Parameter

The Coliform bacteria group consists of several genera of bacteria belonging to the enterobacteriaceae family. Fecal Coliform bacteria are present in large numbers in the feces and intestinal tracts of humans and other warm blooded animals and can enter water bodies from human and animal wastes (Sperling 2002). If over 200 colonies/100 ml of water sample are found, it is possible that pathogenic organisms are also present in the water. Methods commonly used to measure fecal Coliform include the multiple tube fermentation method (the most probable number method, MPN) and the membrane filter method (MF). Fecal coliform bacteria is a measure of the number of colonies counted per 100 milliliter of water sampled. The presence of fecal bacteria in a stream indicates that the water has been contaminated with the feces of warm-blooded animals, which may include human waste (Cech 2003). In addition to the possible health risk associated with the presence of elevated levels of fecal bacteria, they can also cause cloudy water, unpleasant odors, and an increased oxygen demand (EPA, 1997).

2.1.4 Physical Water Quality Parameters- pH

pH represents the effective concentration of hydrogen ions (H^+) in water. This concentration could be expressed in the same type of units as other dissolved species, but [H^+] are much smaller than other species in most waters. pH can be measured with a pH meter, pH paper or by adding a reagent (indicator solution) to the water sample and recording the color change. Some factors that may effect pH are the concentration of carbon dioxide in the water, geology and soils of the watershed that contains acidic and alkaline compounds, air pollution and also drainage from mine sites (Sperling 2002). pH affects many chemical and biological processes in the water. For example, different organisms flourish within different ranges of pH. The largest variety of aquatic animals prefers a range of 6.5-8.0. pH outside this range reduces the diversity in the stream because it stresses the physiological systems of most organisms and can reduce reproduction. Low pH can also allow toxic elements and compounds to become mobile and "available" for uptake by aquatic plants and animals. This can produce conditions that are toxic to aquatic life, particularly to sensitive species like rainbow trout.

Changes in acidity may be caused by atmospheric deposition (acid rain), surrounding rock, and certain wastewater discharges (EPA,1997). Hydrogen ion concentration, a measure of the acidity of a stream, is generally determined in the field. Acidity similar to hydrogen ion concentrations is a measure of the amount of acid producing ions in a sample and is determined in a laboratory setting. Inputs of acidity to the river come from acid rain, organic acids from wetlands (Kozar 1996,), and acid mine drainage (Phares 1971). Additional acid increases the hydrogen ion concentration of a stream unless a stream contains enough alkalinity to neutralize the effects of the acid.

2.1.5 Temperature

The temperature of water is a very important factor for aquatic life. It controls the rate of metabolic and reproductive activities and determines which fish species can survive. It also affects the concentration of dissolved oxygen and can influence the activity of bacteria and toxic chemicals in water. Temperature is measured using a thermometer and recorded in degrees Celsius (^oC) or degrees Fahrenheit (^oF). The factors that affect the temperature includes such as riparian vegetation, flow rate of water, paved surfaces, industrial discharge and sewage outflow (Kozar 1996,). Causes of temperature change include weather, removal of shading streambank vegetation, impoundments (a body of water confined by a barrier, such as a dam), discharge of cooling water, urban storm water, and groundwater inflows to the stream. Temperature affects the oxygen content of the water (oxygen levels become lower as temperature increases); the rate of photosynthesis by aquatic plants; the metabolic rates of aquatic organisms; and the sensitivity of organisms to toxic wastes, parasites, and diseases (EPA, 1997).

2.1.6 Turbidity

Turbidity is a measure of the amount of particulate matter that is suspended in water. Water that has high turbidity appears cloudy or opaque. Turbidimeter is photometer that measures the intensity of scattered light. Turbidity is measured by using turbidimeter. High turbidity can cause increased water temperatures because suspended particles absorb more heat and can also reduce the amount of light penetrating the water. Materials that can causes water to be turbid such as clay and silt, finely divided organic and inorganic matter, plankton, microscopic organism (e.g ; algae) and soluble colored organic compound (eg textile) (White, 1994). Turbidity can affect the color of the water. Consequently it, reduces the concentration of dissolved oxygen (DO) because warm water holds less DO than cold water. Higher turbidity also reduces the amount of light penetrating the water, which reduces photosynthesis and the production of DO. Suspended materials can clog fish gills, reducing resistance to disease in fish, lowering growth rates, and affecting egg and larval development. As the particles settle, they can blanket the stream bottom, especially in slower waters, and smother fish eggs and benthic macro invertebrates (EPA, 1997).

2.1.7 Total Solids

Total Solid is the residue that remains after evaporation and drying at 103 ^{0}C – 105 ^{0}C. It can be divided into two fractions: total dissolved solid (TDS) and total suspended solid (TSS). Total Suspended Solids are separated from dissolved solids by filtering the water through a filter paper. The suspended materials are retained on the filter paper while the dissolved passes through it. The concentration of total dissolved solids affects the water balance in the cells of aquatic organisms (Phares 1971). Higher concentrations of suspended solids can serve as carriers of toxic materials, which readily cling to suspended particles. This is particularly of concern where pesticides are being used on irrigated crops. Where solids are high, pesticide concentrations may increase well beyond those of the original application as the irrigation water travels down irrigation ditches. Higher levels of solids can also clog irrigation devices and might become so high that irrigated plant roots will lose water rather than gain it. A high concentration of total solids will make drinking water unpalatable and might have an adverse effect on people who are not used to drinking such water (Phares 1971). Levels of total solids that are too high or too low can also reduce the efficiency of wastewater treatment plants, as well as the operation of industrial processes that use raw water. Total solids also affect water clarity. Higher solids decrease the passage of light through water, thereby slowing photosynthesis by aquatic plants. Water will heat up more rapidly and hold more heat; this, in turn, might adversely affect aquatic life that has adapted to a lower temperature regime (EPA, 1997). High total solid in water will cause skin irritation, not suitable for recreational activities, and also cause sediment build up thus becomes shallow.

2.1.8 Conductivity

Conductivity is a measure of the ability of water to pass an electrical current (Berg *et al*, 1992). The basic unit of measurement of conductivity is the mho or siemens. Conductivity is measured in micromhos per centimeter (µmhos/cm) or microsiemens per centimeter (µs/cm). Conductivity increases with increasing amount and mobility of ions. These ions that come from breakdown of compounds, conduct electricity because they are negatively or positively charged when dissolved in water. It is indirect measure of the presence of dissolved solids such as chloride, nitrate, sulfate, phosphate, sodium, magnesium, calcium and iron, and it can be used as an indicator of water pollution (White, 1994). Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge). Organic compounds like oil, phenol, alcohol, and sugar do not conduct electrical current very well and therefore have a low conductivity when in water. Conductivity is also affected by temperature: the warmer the water, the higher the conductivity. For this reason, conductivity is reported as conductivity at 25 degrees Celsius (25 ^{0}C), (Berg *et al* 1992).

Conductivity in streams and rivers is affected primarily by the geology of the area through which the water flows. Streams that run through areas with granite bedrock tend to have lower conductivity because granite is composed of more inert materials that do not ionize (dissolve into ionic components) when washed into the water. On the other hand, streams that run through areas with clay soils tend to have higher conductivity because of the presence of materials that ionize when washed into the water. Ground water inflows can have the same effects depending on the bedrock they flow through. Discharges to streams can change the conductivity depending on their make-up. A failing sewage system would raise the conductivity because of the presence of chloride, phosphate, and nitrate; an oil spill would lower the conductivity, (EPA. 1997). Studies of inland fresh waters indicate that streams supporting good mixed fisheries have a range between 150 and 500 µmhos/cm. Conductivity outside this range could indicate that the water is not suitable for certain species of fish or macro invertebrates. Industrial waters can range as high as 10,000 µmhos/cm (Kozar 1996).

2.1.9 Chemical Oxygen Demand

COD is an indication of chemical oxidation of organic material in a water sample. It indicates the degree of pollution in the water sample. Chemical oxygen demand (COD) is a measure of the capacity of water to consume oxygen during the decomposition of organic matter and the oxidation of inorganic chemicals such as ammonia and nitrite. COD measurements are commonly made on samples of waste waters or of natural waters contaminated by domestic or industrial wastes.

Chemical oxygen demand is related to biochemical oxygen demand (BOD), another standard test for assaying the oxygen-demanding strength of waste waters. However, biochemical oxygen demand only measures the amount of oxygen consumed by microbial oxidation and is most relevant to waters rich in organic matter. It is important to understand that COD and BOD do not necessarily measure the same types of oxygen consumption. For example, COD does not measure the oxygen-consuming potential associated with certain dissolved organic compounds such as acetate. However, acetate can be metabolized by microorganisms and would therefore be detected in an assay of BOD. In contrast, the oxygen-consuming potential of cellulose is not measured during a short-term BOD assay, but it is measured during a COD test (Kozar., 1996).

2.1.10 Heavy Metal

Heavy metal pollution is a major environmental problem in the world. The term 'heavy metal' is somewhat imprecise, but includes most metals with an atomic number greater than 20, but excludes alkali metals, alkaline earths, lanthanides and actinides. The heavy metals are those metals that have a density greater than five, include about thirtyeight elements (Salgare, 1991). Apparently, studies on pollution of heavy metals in the urban environment became prominent after the mid sixties, concurrent with enhanced urbanization and industrialization processes worldwide. It was preceded with an earlier shock of mercury poisoning associated with fishes consumed from the Minamata Bay, Japan in the mid fifties (Kudo, 1992).

A study in India revealed that the phsico-chemical characteristics of the water are being altered in the industrial area (Joy et al., 1990). Trace inorganic and organic substances in water supplies originate from natural sources, both plant and animal and also form synthetic organic chemical industry. Heavy metals discharged into a river system by natural or anthropogenic sources during their transport are distributed between the aqueous phase and bed sediments. Sediments are regarded as the ultimate sinks for heavy metal cations (Gibbs, 1973). Hart et al. (1988) demonstrated that the major amount of heavy metals was transported in particulate form (Pb, Zn, Sn ca. 60%, Cu ca. 60%) during a major flood event in the Annan River, Australia. Sediments, not only act as the carrier of contaminants, but also the potential secondary sources of contaminants in aquatic system (Forstner, 1984). Changing environmental conditions in the system may render the remobilization of metals from sediments (Calmano et al., 1993). Malo (1972) had reported that metals in the surface of bottom sediments would be released into the water phase by physiochemical processes. Apparently, the higher the metal concentrations in the sediments, the greater the quantity of metals that could be desorbed from the sediments (Surija and Branica, 1995).

The main threats to human health from heavy metals are associated with exposure to lead, cadmium, mercury and arsenic. These metals have been extensively studied and their effects on human health regularly reviewed by international bodies such as the WHO (Malo, 1972). Cadmium compounds are currently mainly used in re-chargeable nickel-cadmium batteries. The general population is primarily exposed to mercury *via* food, fish being a major source of methyl mercury exposure, and dental amalgam. The general population does not face a significant health risk from methyl mercury, although certain groups with high fish consumption may attain blood levels associated with a low risk of neurological damage to adults. Since there is a risk to the fetus in particular, pregnant women should avoid a high intake of certain fish, such as shark, swordfish and tuna; fish (such as pike, walleye and bass) taken from polluted fresh waters should especially be avoided.

It is well known that the main pollution areas of water bodies and rivers are heavily industrialized cities. At present industrial wastes are prevalent in the composition of the wastewaters of giant industrial cities. Furthermore, the industrial era of the nineteenth century resulted in an acceleration of the use of natural substances such as As, Cd, Hg, Pb, Zn, S, etc., that could eventually be released to the aquatic environment. The current production and use of tens of thousands of synthetic chemicals inadvertently resulted in the release of these substances into the environment. Although industry uses much less water than agriculture, it causes more pollution. Most of the water is used for cooling and cleaning and, although more than 80 per cent of it is returned immediately to the natural water cycle, it is often polluted with by-products of the manufacturing process and other waste material (Hester, 1983). Concentrated effluents from manufacturing and industrial production plants have added hazardous substances to natural water courses and reduced their ability to sustain aquatic life.

Under the WHO monitoring program, cadmium concentrations studied in Sg. Skudai were found to be below detection limit (<0.001 mg/L) (Department of Environment, 1986a). Cadmium also induced changes in the histology of kidneys had been reported in common carp, Cyprinus carpio (Cyprinidae) from the National Fish Seed Farm (NFSF) Jyotisar, India (Singhal and Jain, 1997). Cadmium concentrations in Malaysian rivers recorded levels ranged from 0.06 to 0.48 $\mu g\ g^{-1}$ (Universiti Kebangsaan Malaysia-Department of Environment, 2000). In Central Italy, cadmium was found to be in range of 0.24 $\mu g\ g^{-1}$ to 0.95 $\mu g\ g^{-1}$ in lichens collected from the environs of the town of Pistoia (Loppi, *et al.*, 1994).

2.1.11 Pesticides

Pesticide is a general term applied to herbicides, fungicides and insecticides that are used to kill pests and weeds. They are widely used for weed control in agriculture, on roads and railways, and to control pests in industry. Synthetic organic pesticides were introduced during the Second World War and their use expanded rapidly in the 1950s and 1960s. By providing effective control of pests they have been a great benefit to agriculture, and in conjunction with the use of fertilizers, have increased crop yields considerably. However, by the early 1960s, undesirable effects on the environment were apparent. Rachael Carson drew attention to the risk to groundwater as long ago as 1962 in her classic book Silent Spring. But the measurement of pesticides at low concentration in water is complex and expensive, and the routine examination of groundwater for pesticides is a recent event, as is a more widely perceived appreciation of their risk to groundwater quality.

Pesticides, if used at a minimal amount, are harmless and even help in the production of agriculture by eliminating unwanted pests. But pests soon build up a defense system and are eventually immune to the effects of the pesticides and become very hard to get rid off. So, farmers have no choice but to increase the amount of pesticides applied

The use of organochlorine pesticides has caused concern due to their effects on human health and the Malaysian aquatic ecosystem, particularly so in view of their persistent and bioaccumulative properties. Since the extent of organochlorine pesticide pollution in Malaysian waterways is unknown except for isolated instances, a systematic survey has now been carried out. Water samples from various rivers were extracted, cleaned up with florisil and analysed for the individual organochlorine pesticides by gas chromatography (GC) with an electron capture detector (ECD). DDE, DDT and heptachlor were present in all the river water samples of the west coast of Peninsular Malaysia. Other organochlorine pesticides were also identified from the water samples. However, the levels of all these are still below criteria values for Malaysian aquatic life, indicating that organochlorine pesticide pollution are less of a problem than other organic or inorganic pollutants, (Tan , 1990)

2.1.12 Water Quality Index (WQI)

The quality of water is defined in terms of its physical, chemical and biological parameters, and ascertaining its quality is crucial before use for various intended purposes such as potable water, agricultural, recreational and industrial water uses, etc.

(Sargaonkar and Deshpande, 2003). Water Quality Index is a set of standards used to measure changes in water quality in a particular stream reach over time and make comparison from different reaches of a stream (Debels et al., 2005). The basic methodology used to determine WQI scores was developed by the Environmental Protection Agency (EPA). The index is basically a mathematical means of calculating a single value from multiple test results. WQI is a method of combining several water quality parameters into one concise and objective value representing the state of the water quality trends. The parameters used are Dissolved Oxygen, Biochemical Oxygen Demand, Chemical Oxygen Demand, Total Suspended Solid, ammonical nitrogen and pH.

$$\mathrm{WQI} = 0.22(\mathrm{SI\ DO})+0.19(\mathrm{SI\ BOD})+ 0.16(\mathrm{SI\ COD}) + 0.15(\mathrm{SI\ AN}) + 0.16(\mathrm{SI\ SS}) + 0.12(\mathrm{SI\ pH}).$$

The index represents the level of water quality in a given water basin, such as a lake, river, or stream. The WQI, which was developed in the early 1970s, used to monitor water quality changes in a particular water supply over time, or it can be used to compare a water supply's quality with other water supplies in the region or from around the world (Malo (1972). The result used to determine if a particular stretch of water is considered to be "healthy." The WQI generates a score between 0 and 100. Zero indicates poor water quality while 100 indicates ideal water quality. The WQI is used to give an overall rating of the general or ambient water quality for nutrients and metals; it does not determine the quality of water for specific uses. Scores were grouped into categories based on those derived as excellent, good, fair, marginal & poor (Table 2.1) to provide a relative ranking of the scores calculated for each site within the watershed.

Table 2.1: Water Quality Standards and its intended uses

WQI Water Rating Scale			
Range WQI	Water Quality Status	Class (INWQS-DOE)	Intended Use
91-100:	Excellent	Class I	• Conservation of natural environment
71-90:	Good	Class II	• Water supply with conventional treatment. • Sensitive aquatic. • Recreational use with body contact
51-70:	Medium or average	Class III	• Require extensive treatment. • Tolerant aquatic species.
26-50:	Fair	Class IV	• Irrigation water.
0-25:	Poor	Class V	• Water unsuitable for specific beneficial use.

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Table 2.1 shows that, the WQI range of 91 to 100 as excellent. The river such as Sungai Liawan, Crocker Range Park is classified as class I (Murtedza, 2002) and the river is used as conservation of natural environment. This type of river usually found at the source of that river. There is no pollution and located at hillside. For the range of 71 to 90 (Table 2.1) the status of river is good and it is classified as class II. Class II River used for water supply with conventional treatment, for sensitive special aquatic live and can use for recreational activity with body contact. The river with classification of Class III is under range of 51 to 70. The river of class III is in medium condition and can be used for tolerant aquatic species and it requires extensive treatment if used as water supplies. Under range 26 to 50, the river is classified as class IV. Class IV water is used as an irrigation water and this type of river usually found in the industrial area such as at Sungai Buloh where there are so many illegal factories along the Sungai Hampar which load pollutants into the river and cause the Sungai Hampar to class IV river. Under range 0 to 25 are very poor quality status river system and classified as class V. Class V river is not suitable for any specific beneficial use.

2.1.13 Benefits of Water Quality Monitoring.

Water quality monitoring is defined as the sampling and analysis of water constituents and conditions. These may include introduced pollutants, such as pesticides, metals, and oil. Constituents found naturally in water that can nevertheless be affected by human sources, such as dissolved oxygen, bacteria, and nutrients. Water quality monitoring help to identify whether waters are meet designated uses. All states have established specific criteria (limits on pollutants) identifying what concentrations of chemical pollutants are allowable in their waters. When chemical pollutants exceed maximum or minimum allowable concentrations, waters might no longer be able to support the beneficial uses such as fishing, swimming, and drinking for which they have been designated. It is also to identify specific pollutants and sources of pollution (White 1994).

Water quality monitoring helps link sources of pollution to a stream quality problem because it identifies specific problem pollutants. Since certain activities tend to generate certain pollutants (e.g., bacteria and nutrients are more likely to come from an animal feedlot than an automotive repair shop), a tentative link might be made that would warrant further investigation or monitoring. Chemical constituents that are properly monitored (i.e., consistent time of day and on a regular basis, using consistent methods) can be analyzed for trends over time. Water quality monitoring can use to screen for impairment. Finding excessive levels of one or more chemical constituents can serve as an early warning "screen" of potential pollution problems.

The National Monitoring Network for water quality has been established since 1978 with two major aims stated as to establish the status of river water quality and to detect changes in water quality as a result of development activities. In Malaysia, water quality monitoring activities are conducted by four government agencies in the main respective aspects namely as Department of Environment (DOE), Department of Irrigation and Drainage (DID), The Ministry of Health and Department of Minerals and Geoscience (JMG) (Yusof *et al*, 2006).

Typical reasons for initiating a monitoring project include: Developing baseline characterization data, documenting water quality changes over time, screening for potential water quality problems, providing a scientific basis for making decisions on the management of a stream or watershed, determining the impact of a municipal sewage treatment facility, industrial facility, or land use activity such as forestry or farming, educating the local community or stream users to encourage pollution prevention and environmental stewardship. It shows public officials that local citizens care about the condition and management of their water resources. (EPA, 1997)

2.1.14 Water Quality Status of Malaysian River

According to the Environmental Quality Report 1991, 53 percent of the monitored river basins are classified as clean rivers. With the other 38.9 percent classified as slightly polluted and only 7.4 percent of the rivers are heavily polluted (Table 2.2). For the past decade, this was the only year which shows that the majority of monitored rivers are clean rivers. In 1997, the highest percentage has been recorded in the rivers that are heavily polluted. Hence, the lowest percentage in clean rivers was also recorded in the same year. Reduction of flow would reduce the ability of water in diluting the pollutants. A significant trend of improvement in percentages of river that are heavily polluted could be observed from 1990 – 1997. (Yusof *et al*, 2006)

In Malaysia, such other countries of the world, the level of metal pollution of freshwater bodies, especially the rivers, is no longer within safe limits for human consumption. In the year 2002, the Department of Environment (DOE) reported that industries such as textile, metal finishing and electroplating, food and beverages, and animal feed could not achieve more than 65% compliance. Some industries were operating either without effluent treatment system (ETP) or with inefficient ETP. These industries had difficulty in complying with parameters such as nickel, copper, lead, zinc and iron (Department of Environment, 2002). In Malaysia there are not less than 1500 rivers. Rapid population growth, urbanization and industrialization have subjected some of these rivers 7 to increasing stresses giving rise to loss of firm yield of water and power, sedimentation, flooding, water pollution and environmental deterioration. The Department of Environment

National River Water Monitoring Program got started in 1978, but since 1995, it was contracted out to Alam Sekitar Malaysia Sdn Bhd (ASMA) under a privatization arrangement. In 2003, 926 stations located within 120 river basins in Malaysia were monitored. Out of these 926 monitoring stations, 412 (44.5 %) were found to be clean, 448 (48.4 %) slightly polluted and 66 (7.1 %) polluted. Automatic water quality monitoring stations monitored river quality changes on a continuous basis at Sg. Perai (Pulau Pinang), Sg. Selangor (Selangor), Sg. Kelang (WPKL), Sg. Linggi (Negeri Sembilan), Sg. Melaka (Melaka), Sg. Skudai (Johor), Sg. Perak (Perak), Sg. Keratong (Pahang), Sg. Terengganu (Terengganu) and Sg. Sarawak (Sarawak). Under the pollution prevention and Water Quality Improvement Programme, five (5) additional automatic stations were installed at Sg. Langat (Selangor), Sg. Batang Benar (Negeri Sembilan), Sg. Labu (Negeri Sembilan), Sg. Putat (Melaka) and Sg. Rajang (Sarawak) (Department of Environment, 2003). This is clearly indicated in Table 2.3

Table 2.2 : Malaysian Rivers and its classifications (1999)

No	River	Class of river
1	Sungai Membakut	II
2	Sungai Padas - Beaufort	II
3	Sungai Papar - Kambizaan	II
4	Sungai Kelang	IV
5	Sungai Muar	III
6	Sungai Pahang	III

Table 2.3 River Quality Monitoring Stations for Automatic Continuous Monitoring (1995 - 2003), (Department of Environment, 2003)

Year	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
River basin	2	4	6	8	10	10	10	12	12
Number of automatic continuous monitoring station	2	4	6	8	10	10	10	12	15

Examination of the water quality for streams was clearly indicated marked differences in the level of certain parameters. It was most likely that the elevated levels of pH, conductivity and Ca and Mg contents detected for streams on the interior slopes of Crocker Range Park resulted primarily from the natural leaching of carbonate minerals (Murtedza *et al* , 2002). Aggregate classification based on hydrology-geomorphic-land use, present beneficial use, water quality and aquatic ecology as reported in the Sungai Padas classification study (DOE 1999). Sungai Kelang was classified under Class IV (Ithnin, 1998). This may because it is located at industrial and crowded residential areas. Compared to the Sungai Membakut, Sungai Padas - Beaufort and Sungai Papar – Kambizaan, these rivers were located near hill area. A long range assessment of the water quality of the streams surrounding the Crocker Range Park showed that the rivers situated close to the Park area demonstrated good water quality, mainly of Class II status and occasionally improved to Class I (Murtedza *et al ,* 2002)

2.2 Bioaccumulation of Heavy Metals in Aquatic Life in Sungai Pencala

Bioaccumulations can be divided into direct bioaccumulations and indirect bioaccumulations. The direct bioaccumulations occur mainly through the gill tissue from seawater and digestive tract by ingestion of sediment. Metals absorbed by this mechanism generally show good correlation with concentrations in the external media. The indirect bioaccumulations is mainly through the food chain, such as mercury accumulation in marine biota (Sadiq, 1992).

2.2.1 Substances that bioaccumulates

There are two main groups of substances that biomagnify. Both are lipophilic and not easily degraded. Novel organic substances are not easily degraded because organisms lack previous exposure and have thus not evolved specific detoxification and excretion mechanisms, as there has been no selection pressure from them. These substances are consequently known as 'persistent organic pollutants' or POPs, for examples the DDT and PCBs (Sadiq, 1992). While Inorganic substances consist of heavy metals such as mercury, lead, cadmium, chromium, arsenic and copper. Metals are not degradable because they are elements. Organisms, particularly those subject to naturally high levels of exposure to metals, have mechanisms to sequester and excrete metals. Problems arise when organisms are exposed to higher concentrations than usual, which they cannot excrete rapidly enough to prevent damage. These metals are transferred in an organic form (Mason, 1996). River pollution caused by the direct and indirect discharge of urban and industrial wastes and run-off has lead to the accumulation of toxic compounds such as pesticides, heavy metals (Zhou *et al.*, 2001),.

2.2.2 Factors affecting Bioaccumulations

The concentrations of metal in aquatic organisms vary because they reflect the net effect of two competing process, that of uptake and depuration. The balance between the two will depend upon the ambient water concentrations and the relative rates of the two processes. It also affected by a number of factors, which may introduce a seasonal pattern of variation. Seasonal variations in the physiological condition of aquatic organisms primarily arise from the reproductive cycle and changes in growth rate (Molles Jr, 2005). The reproductive cycle involves the maturation of the gonads and gametes and then spawning. These involve substantial changes in the balance within the organism between proteins, lipids and carbohydrates as well as affecting body weight, water content and general condition of the organism. Period of fast growth are associated with reducing metal concentration in tissues. Low growth results in increasing tissue concentrations. There need be no change in the total body burden for these effects to be evident. Because of these relationships seasonal variations in tissue concentrations (Mance, 1987; Mason, 1996).

Age has long been recognized as important in the interpretation of the metal content of biota both directly and indirectly by weight or physical dimensions. Growth is associated with declining concentrations. It is unlikely that quantitatively reliable relationships of general applicability will be developed for the relationship between age or size and metal content. Besides that, means concentrations of heavy metals differs according to in water depth. As with the interaction between metals in relation to the toxicity of metal to aquatic organisms. It is not only happen between metals but also with other chemicals (Mance, 1987; Mason, 1996).

2.2.3 Bioaccumulation of Heavy Metals

The discharge of large quantities of heavy metal into water resources may cause an adverse effect (Sadiq, 1992). Unlike organic substances, heavy metals does not degrade into less harmful substances and it can accumulate into the soil and water resources which may harm living species if it enters the food chain. There are many possible sources for the heavy metal to enter the river ecosystems. There are point sources and non-point sources.

2.2.3.1 Mercury (Hg)

The environmental behavior of mercury is interesting and differs from those of other toxic elements. Hg is probably the most ubiquitous of all the heavy metals. This is because Hg is the only metal that can exist as both a liquid and as a volatile form at ambient temperatures (Mason, 1996). Due to easy transformation of physical forms, Hg cycles readily and continuously in nature. Mercury is known to biomagnify through aquatic food chain. It is absorbed directly by organisms of the first trophic level. Biological factors such as age, size, and weight are also important to mercury bioaccumulation in fish. It is well established that different body organs concentrate different forms of Hg. It seems that liver tissue prefer to accumulate inorganic Hg and that of muscles tissue methyl mercury. Methylmercury is higher in fish than in other organisms. Concentration of methylmercury is low in liver and medium to high in muscle (Mance, 1987; Mason, 1996).

Mercury and its compounds play an important part in electrochemistry. The metal itself is used as a coolant in certain types of reactors, in the metallurgy of gold and silver, as a catalyst in organic chemistry, and in the manufacture of lamps, relays, and switches. Both mercury and its compounds are highly toxic. Out of the 10 000 tones of mercury produced worldwide yearly, it has been estimated that 25 % is consumed by the chlor-alkali industry, 20 % in electric equipment, 15 % in paints, 10 % in control and measurement system, 5 % in agriculture, 3 % in dental practice, 2 % in laboratory and 20 % in others which include detonators, catalysts, preservatives and cosmetics (Palmer, 1995). Nevertheless, major uses in Malaysia also cover the above-mentioned areas including chlor-alkali industry, electrical equipment, paints and dental practice. In a recent survey of a wide range of paint products available in local market, 12 out of 16 brands of emulsion paints were found to contain mercury ranging from 0.005 % to 0.066 %, while 5 out of 7 brands of gloss pints (solvent based) range from 0.003 to 0.037 % (Department of Environment, 1985).

Apparently, a monitoring study found 0.1 mg/L concentration of Hg in Sg. Skudai (Department of Environment, 1986b). Meanwhile in Sg. Langat, mercury level is reported to be 0 to 0.004 mg/L (Law and Singh, 1986). Because of the toxic nature of mercury, the Malaysian government established a limit for public water supplies of 0.002 mg/L of mercury. The average concentrations for aquatic plants, benthic invertebrates and fish in the Ottawa River were 14.2 ppb, 233 ppb and 162 ppb, respectively, for total mercury (Kudo, 1992). In Canada, Stokes and Dreier (1983) reported that concentration of mercury in water were (10 - 30 ng/ L) and sediment concentrations were quite variable from 36 to 150 ng/g. Polprasert (1982) reported that mercury levels in aquatic plant from the Chao Phraya river estuary ranged from 0.75 to 1.26 ppm in leaves and 0.28 to 0.68 ppm in floating stems.

2.2.3.2 Lead (Pb)

Lead contamination of the aquatic ecosystems is increasing because of emission outfalls and industrial effluent discharges. Lead can be accumulated directly from seawater and sediments especially aquatic organisms, which utilize gill tissue as the major nutrient uptake route. The chemical form affects the biological accessibility of Pb to aquatic organisms, as does the chemical portioning of Pb in the sediments. Concentration of Pb in aquatic sediment varies widely because anthropogenic inputs are the major sources of contamination. Relatively higher concentrations of Pb are expected in the coastal sediments and those in the vicinity of pollution point sources (Mance, 1987; Mason, 1996).

Previous studies of Sg. Semenyih showed levels of lead ranging from 0.1 to 1.76 µg /L (Department of Environment, 2002). Lead poisoning in children was also traced to the consumption of lettuces containing high levels of the element. The sources of Pb were found to be old lead batteries that had been dumped on the ground within the neighborhood of vegetable plots (Lepp, 1981b). NAS (1976) reported that grass was contaminated by lead within 152 m downwind of roads in Colorado, USA. It was also reported that lead in soils ranged from 128-700 µg/g . Whereas, the monitoring study conducted by WHO found that the concentration of lead in the Sg. Skudai river water was 0.8 mg/L (Department of Environment, 1986a). In Poland, herbs were found containing 0.94 mg /kg of lead (Lozak *et al.,* 2001).

2.2.3.3 Cadmium (Cd)

Cadmium is a priority pollutant, which enters aquatic ecosystems *via* both atmospheric deposition and effluent discharges from point sources. Because of extensive industrial usage, anthropogenic inputs into the environment are the main source of Cd contamination. Cadmium, like any other element, can be biomagnified either directly from sediment or *via* the food chain. In organisms that utilize gill tissue as a major uptake route, Cd bioaccumulation is directly related to its concentrations in the water. Within the body of a aquatic organism, bioaccumulation of Cd is selective, localizing in certain tissues. Sites of Cd localizing may vary from organism to organism (Mance, 1987; Mason, 1996).

On the contrary, absorption through food is the most important route of cadmium uptake for the general population. Acute ingestion of contaminated food and drink causes nausea, vomiting, abdominal cramps, diarrhoea and shock. Chronic inhalation of cadmium fumes produces effects on the kidneys causing renal tubular damage, lung emphysema as well as anaemia, liver damage and later disturbances in calcium/phosphate metabolism. An incident due to chronic ingestion that shows rise to renal tubular damage is the itai-itai disease in Japan (Lepp, 1981a). In Malaysia, the death dose for cadmium poisoning is 10 mg (Food Act, 1983).

Under the WHO monitoring program, cadmium concentrations studied in Sg. Skudai were found to be below detection limit (<0.001 mg/L) (Department of Environment, 1986a). Cadmium also induced changes in the histology of kidneys had been reported in common carp, Cyprinus carpio (Cyprinidae) from the National Fish Seed Farm (NFSF) Jyotisar, India (Singhal and Jain, 1997). Cadmium concentrations in Malaysian rivers recorded levels ranged from 0.06 to 0.48 µg/g (Universiti Kebangsaan Malaysia-

Department of Environment, 2000). In Central Italy, cadmium was found to be in range of 0.24 µg/g to 0.95 µg/g in lichens collected from the environs of the town of Pistoia (Loppi, et al., 1994).

2.2.3.4 Chromium (Cr)

Chromium is an anthropogenic pollutant. Its contamination results mainly from human activities. Therefore, Cr concentrations are expected to be high in the estuarine system and freshwater systems. Cr passes readily through the gills and accumulates in other organs. Chromium may accumulate differentially in different types of tissue; high concentration of Cr is found in kidney followed by liver and muscle in fish. It is found that Cr accumulates rapidly and depurates slowly (Humtsoe *et al.*, 2007).

Chromium is widely distributed in the earth's crust, though concentrations are generally relatively low, at about 0.04 per cent of the total solid matter: Its toxicity to industrial workers has been recognized for many years. The most common industrial sources are the alloy industry, wood treatment, and chromium mining operations. Besides that, Cr is used extensively for manufacture as stainless steels, decorative and wear resistant surface treatments and manufacture of chemicals. Furthermore, chromium salts are used in chemical analysis tanning, dyeing, ceramics, and in the dyestuffs industry. The major uses of chromium are in the metallurgical industry for the production of stainless steel and other alloy steels, and in the refractory. Other uses are in the electroplating, metal finishing and leather tanning industries and in the production of fungicides, pigments, oxidants, and catalysts and in the glass and photographic industries (Stoeppler, 1992).

The usage of chromium and its compounds is estimated almost 10-100 million tones per year (Mason and Moore, 1982). Chromium is a mixture of 4 isotopes of masses 50, 52 (83.76%), 53 and 54. The boiling point for chromium is 2672 ^{0}C (Herold and Fitzgerald, 1994).

2.2.3.5 Arsenic (As)

The bioaccumulation of As in aquatic environments is interesting and probably unique. Levels of As in the terrestrial or freshwater organisms are seldom high in concentration. This could be due to different chemical forms of As in freshwater. Concentration of As vary widely within marine organisms and seem to be affected by their feeding habits. In general, bottom feeders accumulate more As in their soft tissues than the fishes. Bioaccumulation of As is influenced by the route of uptake by aquatic organisms.

Direct uptake which is absorption by gill tissues is more dependent on concentrations in the external media than indirect uptake. As accumulation is influenced by its concentrations in the water itself, especially in organism that utilize gill tissue as the main route for nutrient uptake (Humtsoe *et al.,* 2007). Besides that, from the studies in Sg. Langat basin, levels of arsenic have been reported to range between 0.003 to 0.049 mg/L (Department of Environment, 1998). Accumulation of arsenic in herbs in Poland was found to be 1.05 mg/kg (Lozak *et al.,* 2001).

2.3 Solid waste characterization

Waste is a substance or object which is disposed off or is intended for disposal (Basel Convention, 1989). Solid waste comprises all the wastes arising from human and animal activities that are normally solid and that are discarded as useless or unwanted (Tchobanoglous, 1993). People throw things away when they do not have a use for them or think they have no obvious value. Garbage, refuse or other waste matter of a solid nature can be classified as solid waste.

Solid waste characterization means finding out how much paper, glass, food waste, etc. is discarded in waste stream (McCauley-Bell et al, 1997). Waste characterization information helps in planning how to reduce waste, set up recycling programs, and conserve money and resources. Waste characterization information is designed for solid waste planning; however, anyone interested in the characteristics of the solid waste stream may find it useful. Local government planners, haulers, and recyclers may estimate the amount of certain materials in their waste stream through the waste characterization database. Waste characterization data is collected by taking samples of waste and sorting it into material types like newspaper and aluminum cans, and weighing each type (McCauley-Bell *et al*, 1997).

2.3.1 Sources of Solid Waste in Water System

Waste generation in Malaysia was found to depend very much on the sources of municipal solid waste (MSW). The rate of generation varies greatly depending on the premises (house, shop, etc), affluence of population (low or high income), occupation or business (Agamuthu *et al*, 2004). Housing area generates the largest amount of waste (Figure 2.1). Table 2.3 summarizes the municipal solid waste from various sources of waste generator in Petaling Jaya, Malaysia (Agamuthu *et al,* 2004). The squatters who usually occupy land at the riverside or next to high tension cable lines generate the highest amount of solid waste (3.42 kg/dwelling/day). Assuming an average of 5-6 occupants per dwelling, each person generates 0.61 kg/day. Source of solid waste can be categorized as municipal, commercial, industrial, construction, mines and quarries and agricultural (Rosta and Puziah, 2006). It waste composition is different depending on source of generation.

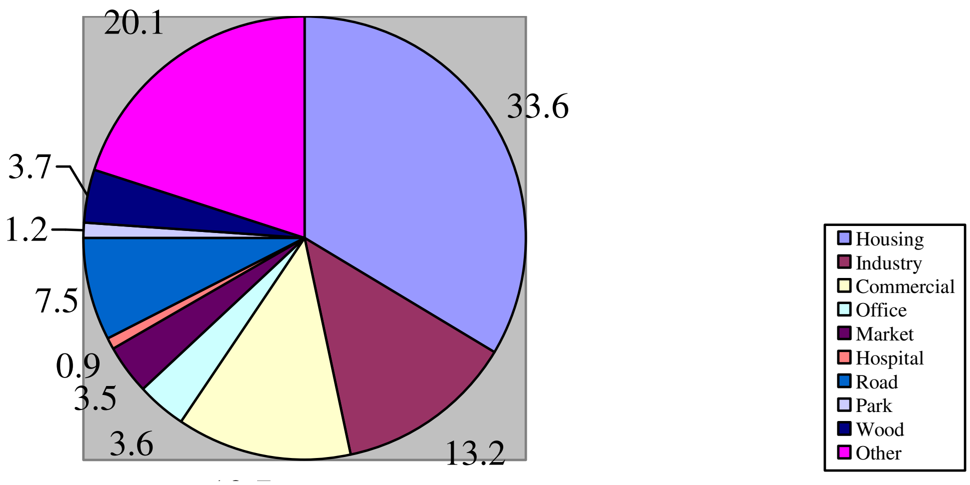


Figure 2.1: Percentage of Waste Generation in Malaysia, Agamuthu *et al*, 2004

2.3.2 Types of Solid Waste

Solid waste from paper and paperboard categories includes corrugated container. This paper can be used as facing material for corrugated or solid fiber containers. Brown paper bags are included in this category. Examples would be cardboard boxes and containers. Mixed Paper means unsegregated by color or quality, of at least two of the following paper wastes: newspaper, corrugated cardboard, office paper, computer paper, white paper, coated paper stock, or other paper wastes. Newspaper that is separated from other types of solid waste or collected separately from other types of solid waste and made available for reuse and be used as a raw material in the manufacture of a new paper product. High Grade Ledger Paper is office white letter paper or computer print paper of non-colored variety with fiber content and consistency that is of presentation quality. Examples of non-recyclable paper products are foil and paper wraps, waxed paper, and plasticized paper (Hoornweg *et al,* 1999)

Figure 2.2: Plastic Waste

Figure 2.3: Metal Waste

For glass categories, recyclable glass includes refillable glass beverage containers, and other recyclable glass. Examples of non-recyclable glass are pyrex, plate glass, automotive glass, light bulbs, etc. In metal categories, it includes ferrous, non ferrous and aluminium cans. Examples of ferrous are any iron or steel scrap that has iron content sufficient for magnetic separation, including tin and bi-metal cans. For non ferrous, any metal scraps that have value and are derived from metals other than iron and its alloys in steel and to which a magnet will not adhere. Examples of non-ferrous metals are aluminum, copper, brass, bronze, lead, and zinc. Aluminum Cans is any food or beverage container that is composed of at least 94 percent aluminum. (Hoornweg *et al*, 1999).

Organic waste is one of the primary types of solid waste. Figure 2.4 and Figure 2.5 show the examples of organic and inorganic waste. Yard and garden waste (Any waste from maintaining or altering of public, commercial, or residential landscaping, yard clippings, leaves, tree trimmings, etc), food waste, wood, textile, leather and rubber (Products of an amorphous polymer of isoprene derived from natural latex of certain tropical plants or from petroleum) is the secondary types of organic waste. As for inorganic waste, the secondary category includes rock, brick, ceramic and plaster. Small appliance is other types of solid waste. Computer, television and stereo equipment are the examples of these types of solid waste (Hoornweg *et al,* 1999).

Figure 2.4: Organic and Inorganic Waste

Figure 2.5: Organic Waste

Hazardous waste is wastes from products purchased by the general public for household use which, because of their quantity, concentration, or physical, chemical, or infectious characteristics, may pose a substantial known or potential hazard to human health, or the environment, when improperly treated, disposed, or otherwise managed. Examples are cleaning solvents, sprays, insecticides, herbicides, pharmaceuticals, etc. The example of hazardous waste illustrates in Figure 2.6 to Figure 2.8. Bulky object include white goods as example. Discarded, enamel-coated major appliances, such as washing machines, clothes dryers, hot water heaters, stoves, and refrigerators are example of white goods. (Hoornweg *et al,* 1999).

Figure 2.6: Hazardous Waste

Figure 2.7: Hazardous Waste

Figure 2.8: Bulky Object

2.3.3 Waste Composition

Malaysia generates about 72% of compostable waste comprising organic waste, paper, textile and wood (Agamuthu et al, 2004). In Petaling Jaya , the amount of plastic waste, which accounts for 16.4% of is considered very high and is typical of a fast developing nation (Agamuthu et al, 2004). Garbage is the main component with 36.5%. Paper and cardboard is the second most abundant component (27%) whereas plastic was at 16.4% (Agamuthu et al, 2004). Table 2.6 show the solid waste composition of Petaling Jaya, Malaysia.

Table 2.4 Solid Waste Composition (% by weight) of Petaling Jaya, Malaysia

Waste Composition	Percentage
Garbage	36.5
Plastics	16.4
Bottle/Glass	3.1
Paper/Cardboard	27.0
Metals	3.9
Fabric	3.1
Miscellaneous	10.0

Source: Malaysian Industry, April 1997

CHAPTER III

EXPERIMENTAL & METHODOLOGY

3.0 Experimental and Methodology

3.1 Water Quality Studies

Increased urban activities are deteriorating the health of the rivers in Malaysia. Despite controlled measures taken by the government and other relevant authorities, pollution loading from point and diffuse (non-point) sources are affecting the rivers in various ways (Abdullah-Al-Mamun, 2006).

Water quality studies helps link sources of pollution to a stream quality problem because it identifies specific pollutants. Since certain activities tend to generate certain pollutants a tentative link might be made that would warrant further investigation or monitoring. Chemical constituents that are properly monitored (i.e., consistent time of the day, using consistent methods and on a regular basis) can be analyzed for trends over time. Water quality monitoring can also be used to screen for impairment. Finding excessive levels of one or more chemical constituents can serve as an early warning "screen" of potential pollution problems.

We depend on surface and groundwater sources for drinking water, to generate energy, to grow our crops, to harvest fish, to run machinery, to carry wastes and to enhance river scenic landscape. We use water for washing and cleaning, industrial abstraction, recreation, cooking, gardening and angling. Freshwater is also vital as a habitat for fish, invertebrates such as mayflies, shrimps and snails and also many water plants. The Department of Environment has a regulatory function to control discharges into rivers. The effectiveness of the regulatory work can only be determined by monitoring. In addition, the monitoring process can identify developing problems to enable them to be addressed as swiftly and effectively as possible.

3.1.1 Sampling Plan

Sampling is the collection of a representative portion of water samples from each sampling point. The analysis of samples provides information on the water quality characteristics of each sampling site. Consistency in the sampling method is essential for statistical analysis of the collected data. The frequency of sampling is dependent on individual study needs. At the pre-fieldwork stage, a sampling design was developed to cover all 14 points of the river.

3.1.2 Selection of Sampling Site

Sampling site was selected based on the surrounding land use and the number of stream running out of the area. At the pre-fieldwork stage, a clear sampling plan was developed to focus on areas that seem to have more pollution. Before going to the field work, the necessary arrangements were made for sampling. A sampling location map that labels the sampling site was prepared. A field data sheet was prepared to record specific information such as date & time of sample collection, weather conditions which are important when interpreting data. Water samples were collected from 14 sampling location as shown in Figure 3.1

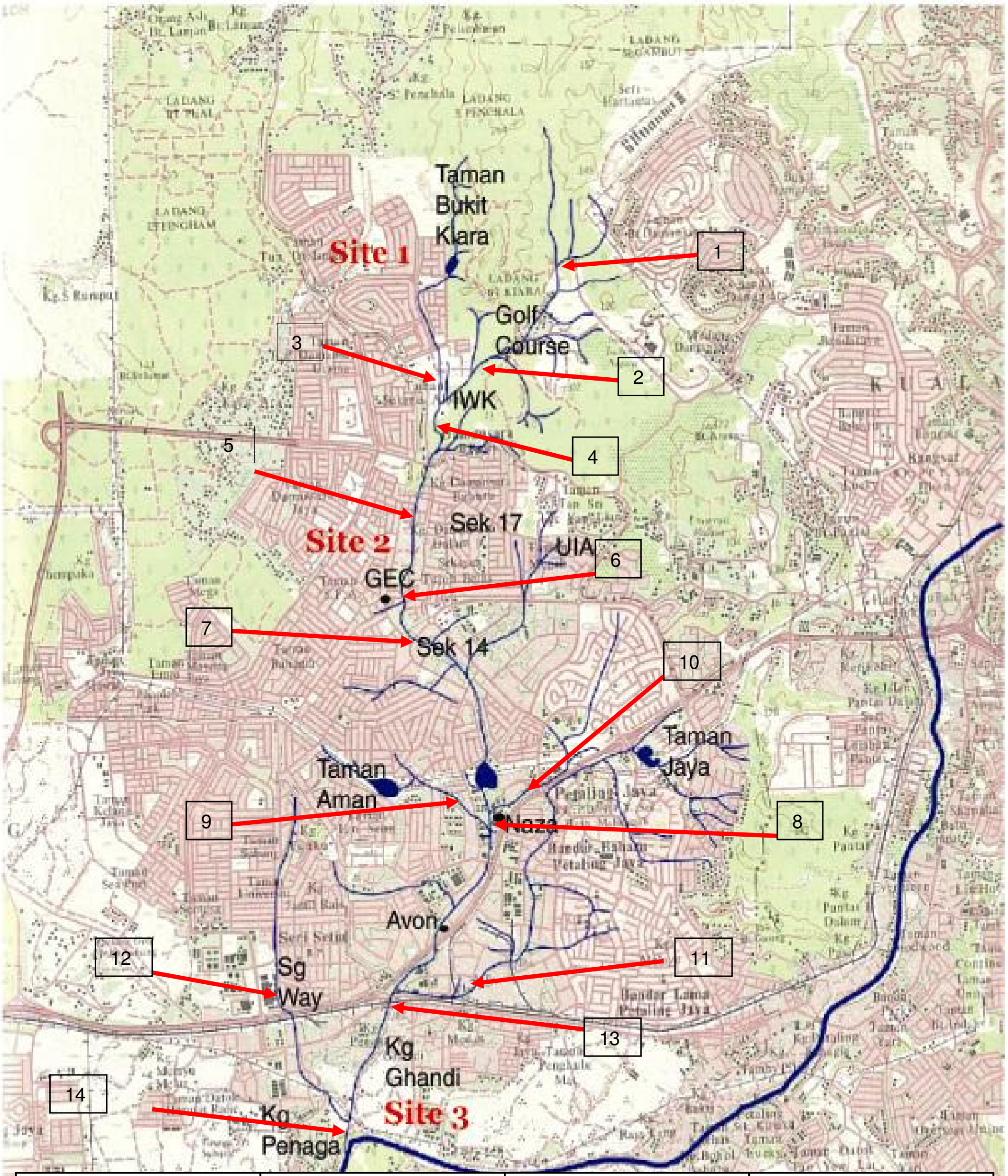
Table 3.1: Description of sampling location at Sungai Pencala

Locations ID	**Description**
W 1	Stream upon Bukit Kiara
W 2	After KLGCC before Rimba Kiara
W 3	Behind TTDI market
W 4	After the bridge Caltex petrol station
W 5	A long Section 19
W 6	Near Jalan SS2
W 7	Bridge behind BAT
W 8	NAZA showroom
W 9	Tributary from Taman Aman
W 10	Tributary from Taman Jaya
W 11	Tributary from Jln Templer/Tandang
W 12	Tributary from Sg Way (guinnes)
W 13	After the Federal Highway (AVON)
W 14	Kg Medan (Sg Klang)

3.1.3 Sampling Location

Sungai Pencala has an area of 28 square kilometers. It is drained by 31.4 km of trunk drains-main drainage channel (approximately 12 km) discharges into Sungai Klang and formed by two tributaries starting from Bukit Kiara – one flows through the KL Golf and Country Club (KLGCC) and the other through Kiara Park in Taman Tun Dr Ismail (TTDI) (Figure 3.1). The tributary in TTDI flows through the beautiful Lembah Kiara Park where it eventually turns into a canal lined with terra-cotta bricks. Unfortunately, the artificial canal deprives the stream of its natural filtering function. The river continues downstream into the highly populated urbanized TTDI township where the stream is deepened, widened, and turned into a concrete channel. Pollution starts here with residential drainage network feeding it with domestic waste water and leaking sewage.

Pencala River & Tributaries



W1 : Stream upon Bukit Kiara	**W2 : After KLGCC before Rimba Kiara**	**W3 : Behind TTDI market**	**W4 : After the bridge Caltex petrol station**
W5 : A long Section 19	**W6 : Near SS2**	**W7 : Bridge behind BAT**	**W8 : NAZA showroom**
W9 : Tributary from Taman Aman	**W10 : Tributary from Taman Jaya**	**W11 : Tributary from Jln Templer/Tandang**	**W12 : Tributary from Sg Way (guinnes)**
W13: After the Federal Highway (AVON)		**W14 : Kg Medan (Sg Klang)**	

Figure 3.1 Sampling sites along Sungai Pencala

The pollution increases when the river enters the Petaling Jaya district where it flows through many residential and industrial areas. Sungai Pencala, ill-fatedly has adopted heaps of residential and industrial waste and rubbish. The quality of the river steadily deteriorates as it meanders further downstream, and worse, it begins to look like an open sewer. Its murky water laden with all kinds of waste and rubbish caused by anthrogenic activities.

In this current study, fourteen sampling points were selected to assess the water quality of Sungai Pencala. Sampling points along Sungai Pencala are shown in Figure 3.1. The sampling locations for each station are shown in Figures 3.2 to 3.15

Figure 3.2 Sampling location W-1;Stream at Bukit Kiara

Figure 3.3 - Sampling location W-2; After KLGCC before Rimba Kiara

Figure 3.4 - Sampling location W-3; Behind TTDI Market

Figure 3.5 Sampling location W-4; After the Bridge near Caltex Petrol Station

Figure 3.6 Sampling location W-5; At Section 19

Figure 3.7 Sampling location W-6; Near SS2

Figure 3.8 Sampling location W-7; Bridge behind BAT

Figure 3.9 Sampling location W-8; Near Near Naza Showroom

Figure 3.10 Sampling location W-9; Tributary from Taman Aman

Figure 3.11 Sampling location W-10; Tributary from Taman Jaya

Figure 3.12

Sampling location W-11; Tributary from Jalan Templer Tandang

Figure 3.13 Sampling location W-12; Tributary from Sungai way

Figure 3.14 Sampling location W-13; After the Federal High way Avon

Figure 3.15 Sampling location W-14; Klang Medan where Sg.Pencala meets (Sg. Klang)

3.1.4 Field Work

The field data collection was carried out routinely from March 2006 to June 2007. The field work involved *in situ* measurements and collection of samples for laboratory analyses.

Water samples were collected at designated sampling points in Sungai Pencala (Figure 3.1) using Van Dorn water sampler for *in situ* and laboratory analysis. Sampling procedure including sample preservation was carried out in accordance with APHA (2005). Each sample was stored in 1000 ml plastic bottles (HDPE). At every single sampling point, about 100 ml samples were collected for heavy metals analysis. The samples were kept in polyethylene bottles and preserved with ultra pure nitric acid to pH<2 and kept at 4 ^{0}C for heavy metal analysis. Solvent rinsed amber glass bottles were used for sample collection for pesticide analysis. All samples were labeled with the station numbers, date and time of collection accordingly. Immediately after collection, the samples were kept in the ice box (Coleman) and stored at 4^oC for preservation prior to testing or laboratory analysis. Samples were analyzed in the laboratory for BOD, COD, total solids, total dissolved solids, conductivity, heavy metals such as cadmium, arsenic, Lead, mercury, ammonia nitrogen, pesticides, total plate count and coliform. All the parameters were analyzed using standard test method.

Field measurements and observations were recorded in a field data sheet for each sampling trip. There were 14 monitoring stations in Sungai Pencala for which samples have been collected and analyzed. pH, dissolved oxygen, temperature, turbidity results were determined *in situ* at each station using instruments mentioned in Table 3.2

Table 3.2 – Field Instruments

Parameters	**Analysis Type**	**Instruments/ Model**	**Method Reference**
pH	*In situ*	Cyber Scan 197 pH Meter , Eutech Instruments	APHA 4500-H^+ B
Temperature	*In situ*	Cyber Scan 197 pH Meter , Eutech Instruments	APHA 4500-H^+ B
Turbidity	*In situ*	Hach 2100P Turbidimeter Eutech Instruments	APHA 2130
Dissolved Oxygen	*In situ*	Cyber Scan DO 300 Eutech Instruments	APHA 4500-O G
Conductivity	*In situ*	Cyber Scan 200 Eutech Instruments	APHA 2510 B

3.1.4.1 pH

The basic principle of electrometric pH measurement is determination of the activity of the hydrogen ions by potentiometric measurement. pH meter was used to measure pH. pH meter was calibrated before use and rinsed with the distilled water. pH meter Cyber Scan 197 pH Meter was used for *in situ* measurement. pH meter was calibrated according to the manufacturer's instructions by using pH buffer solution 4.0 and 7.0. At each station, pH meter was turned on and the probe was placed into the water column and the pH was reading stabilized recorded for each station until the meter reading stabilizes before recording the pH and the temperature. The probe was rinsed with distilled water after use.

3.1.4.2 Temperature

Temperature is a measure of how cool or how warm the water is, expressed in degrees Celsius (C). Temperature is a critical water quality parameter, since it directly influences the amount of dissolved oxygen that is available to aquatic organisms. Temperature probe was used for obtaining temperature results. Finally, the temperature was in a data sheet.

3.1.4.3 Dissolved Oxygen

Dissolved Oxygen meter, Cyber Scan DO 300 was used for measuring DO and the data was recorded in a data sheet. DO meter and the probe were calibrated and checked and compared with Winklers titration to check the DO probe for its accuracy before use. At each station, the meter was turned on and the probe was placed into the water column. Sufficient time was allowed for the probe to stabilize before recording the dissolved oxygen. Readings were recorded and the probe was rinsed with distilled water after use.

3.1.4.4 Turbidity

Turbidity is measured in Nephelometric Turbidity Units (NTU). Turbidity Meter , Hach 2100P Turbidimeter, Eutech Instruments was used to record NTU results. The instrument was calibrated according to the manufacturer's instructions using 40, and 400 NTU solutions. Samples were well mixed by turning the sample bottle upside down 2-3 times before measuring the results were recorded in field data sheet.

3.1.5 Laboratory Analysis

After the field work the samples were taken to the laboratory for analysis with ice preservation. Summary of collection and preservation of samples at Sungai Pencala are detailed in Appendix A.

3.1.5.1 Chemicals and Materials

- Pure water for all laboratory analysis was obtained from Aquamax Ultra pure De ionizing Water treatment unit with 0.22 µm filter.
- Whatman's Glass Fiber filter paper
- Nitric Acid, HNO_3 Trace Metal Grade, Fisher Scientific
- Sulphuric acid, H_2SO_4 (96%) Systerm chemicals ChemAR
- Perchloric acid, $HClO_4$
- Hydrogen Peroxide, H_2O_2, 33%.
- Potassium Dichromate, $K_2Cr_2O_7$ AR Grade , Fisher Scientific
- Potassium hydrogen phthalate standard (Systerm ChemAR Grade)
- Silver sulphate, $AgSO_4$ (Systerm ChemAR)
- Bio seed, purchased from Bio Systems International.
- Calcium chloride, (Systerm ChemAR)
- Magnesium sulfate monohydrate (Systerm ChemAR)
- Mercuric sulfate (Systerm ChemAR)
- Manganese sulfate, Systerm ChemAR
- Sodium iodide Systerm ChemAR

- Sodium thiosulfate, Systerm ChemAR
- sodium nitroprusside (Syesterm ChemAR grade)
- ICP Multi element standard ,Merck Certipur ICP Multi element Standard
- Potassium permanganate (Fisher Scientific AR Grade)
- Potassium persulfate (Systerm ChemAR)
- Mercury Standard (Merck Mercury Standard 1000 ppm).
- Methylene chloride (Merck HPLC Grade)
- Phenol, (Merck, ACS grade)
- Sodium Hydroxide, (Systerm ChemAR
- Potassium Hydroxide, (Systerm ChemAR
- EDTA, HmbG Chemicals
- Hydroxyl Ammonium Chlroide, (Systerm ChemAR)
- Stannous chloride, (Systerm ChemAR

3.1.5.2 Conductivity and Total Dissolved Solids

Samples were analyzed for conductivity and total dissolved solids using conductivity meter. Conductivity meter was calibrated using potassium chloride standard solution. Samples were brought down to room temperature before measurement. Conductivity and TDS were measured by switching appropriate mode on the conductivity meter to directly display in conductivity in units of micromhos/cm and TDS in units of mg/l.

3.1.5.3 Total Suspended Solids

Total suspended was determined according to method APHA 2540 D. A sample volume of 100 ml was filtered through a pre washed, dried and weighed Whatman’s Glass Fiber filter paper using a vacuum pump unit. The filter paper was then dried at 103 ^{0}C for 1 hour, and cooled in a desiccators and reweighed using a calibrated balance to the nearest 0.01 mg.

The total suspended solid was calculated by using the following expression,

$$\text{TSS (mg/l)} = \frac{\text{Final weight(g) - Initial weight(g)} \times 1000000}{\text{Volume (ml)}}$$

3. 1.5.4 Chemical Oxygen Demand

Chemical Oxygen Demands for all water samples were analyzed using a closed reflux digestion procedure as per APHA 5220D. Most type of organic constituents was oxidized by a boiling mixture of chromic and sulfuric acid. Sample was refluxed with strong sulphuric acid, and with known excess of potassium dichromate ($K_2Cr_2O_7$) using a block digester in a 10 ml capacity screw top culture tubes. The measurement of consumed dichromate was measured against standards with a UV /Visible Varian Model, Cary 50 UV/Visible spectrophotometer. The limit of reporting from the method validation data is 2 mg/l. Digestion was done using only 16 x 100mm high quality borosilicate glass tubes with the screw caps for digestion. All tubes were thoroughly cleaned with chromic acid, rinsed well with de ionized water, and dried prior to use. Digestion reagent blank, quality control standard, spiked samples and a series of five working calibration standards from stock potassium hydrogen phthalate standard were prepared for every analysis.

For Low and High COD range, only 2.5 ml of sample and calibration standards were added to the appropriate tubes. 3.5 ml of digestion reagent was added to the samples, blanks and series of standards. Digestion reagent was prepared by dissolving 10.216 g of $K_2Cr_2O_7$ (dried at 100^0 C for 2 hrs), 167 ml of concentrated H_2SO_4 and 33.3 g of

$HgSO_4$ at room temperature in 500 ml of water, then 2 ml of sulphuric acid mixture which was prepared by mixing 10.1 g of Ag_2SO_4 in 1000 ml of concentrated sulfuric acid was added. The same procedure was applied to all calibration standards, samples, QC standards, blanks and spiked samples. The tubes were tightly closed and carefully inverted the tubes once to mix the two layers. After the addition of reagents was completed, all the tubes were placed into the block digester, and the timer was set for 120 minutes at 150 ^{0}C. Laboratory control and spike samples were analysed at 50 ppm and the recoveries are shown in Appendix B.

Tubes that turned to green at this stage were discarded, and the experiments were repeated after dilutions. If the samples turn green with low method, repeat with High method or further dilutions. The tubes were then taken out from hot block for cooling and the absorbance were measured at 349 nm using UV-VIS spectrophotometer meter and compared against calibration standards and the results were computed against the calibration curve.

3. 1.5.5 Biological Oxygen Demand (BOD 5 days at 20 ^{o}C)

Dissolved oxygen was measured initially and after incubation, and the BOD was computed from the initial and final Dissolved Oxygen as per APHA 21st Edition 5210 B. A dissolved oxygen probe was used to determine the concentration of dissolved oxygen concentration of reference was made to the determination of dissolved oxygen by Winkler's titration method where interferences may occur with the probe method. Commercially available Bio seed, was hydrated at a rate of half a capsule to 500 ml nutrient water for a minimum of 1 hour, and then was added to BOD Bottles (2.0 ml per bottle). The dilution water was prepared by aerating pure reverse osmosis (RO) water using the bubbler for a minimum period to saturate the water with oxygen and ensured that the dissolved oxygen was at least 7.5 mg/l. The dilution water was “seeded” with a bacterial culture using hydrated bio seed. To ensure accurate results, the samples were suitably diluted with specially prepared dilution water so that adequate nutrients and oxygen were available during the incubation period. Three dilutions were prepared to cover the complete range of possible values.

Dissolved oxygen was determined at the beginning and end of a 5 day period incubated at 20 °C using oxygen probe. The ranges of BOD were measured with various dilutions based on percentage mixtures. Glucose glutamic acid standard was analysed along with each batch of sample and the BOD was calculated using equation below,

BOD, mg/l = $(D_0 - D_5) - (B_0 - B_5)$ x f x (300/ml sample) x Primary Dilution (if any)

D_0 = DO of sample on day 1
D_5 = DO of sample on day 5
B_0 = DO of seeded blank on day 1
B_5 = DO of seeded blank on day 5
f = Seed factor

3. 1.5.6 Ammoniacal Nitrogen

Alkaline phenol and hypochlorite react with ammonia to form indophenol blue that is proportional to the ammonia concentration. The blue colour formed is intensified with sodium nitroprusside and the absorbance is measured at 640 nm using Varian UV/visible spectrophotometer. Ammoniacal Nitrogen was determined using Varian model, Cary 50 UV/Visible Spectrophotometer, as per APHA 21st Edition 4500 NH3 F 25 ml of sample was taken in a 50 ml volumetric flask and 1 ml phenol, solution, 1 ml sodium nitro prusside solution and 2.5 ml oxidizing solution mixture of alkaline citrate and sodium hypochlorite solution were added with thorough mixing after each addition.

A Calibration standard curve was prepared using blank, 0.1, 0.2, 0.5 and 1.0 ppm of a standard ammonium solution. Calibration standard and the samples were allowed to stand for 1 hr and the absorbance was measured at 640 nm by UV/visible Spectrometer. Sample concentrations were computed by comparing sample concentration with the standard calibration curve. The quality control sample and the spike samples were analysed at 1.0 mg/l level with each batch of analysis and the recoveries are shown in Appendix B.

3. 1.5.7 Heavy metals Analysis

Water samples were collected in a100 ml HDPE container and were acidified to pH <2 using nitric acid (HNO_3) for total metals analysis. The analysis were carried out by following Standard test method APHA 3120 B. Sample preparations were done according to APHA 3030E using a nitric acid digestion.

50 ml of a well-mixed, acid-preserved sample appropriate for the expected metals concentrations to a flask or beaker and 2.5 mL of conc HNO_3 was added and covered with a ribbed watch glass to minimize contamination. Boiling chips, glass beads, or Hengar granules was added to aid boiling and minimize spatter at high concentration levels The solution then was slowly boiled and evaporated on a hot plate to the lowest volume possible before precipitation occurred and the heating was continued by adding conc HNO_3 as necessary until the digestion was completed as the solution become a light-colored, clear solution. The flask or beaker walls and watch glass were rinsed with metal-free water and then the solution was filtered. The filtrate was transfer filtrate to a 50-mL volumetric flask and these rinsings were added to the volumetric flask, cooled, dilute to mark and mixed thoroughly. The filtrate was then analysed using an

Inductively Coupled Plasma Emission Spectrometer (ICP-AES) (Perkin Elmer 5300 Model) for cadmium, arsenic, lead, chromium. The water samples were continuously monitored at the same location for a period of 1 year.

A calibration standard was prepared from a stock solution of 100 ppm multi elements standard with appropriate dilutions. The calibration range was from 0.1 to 10 ppm. The results were computed against a calibration standard curve. The laboratory quality control samples and spike samples were analysed at 1.0 ppm level on ICP AES, and summarized in Appendix B

The very low concentrations of heavy metals pose significant difficulties to the use of Inductively Coupled Plasma Atomic Emission Spectrometer (ICP-AES). Hence some of the batch sample analyses were carried out using Inductively Coupled Plasma Mass Spectrometer (ICP-MS) model Perkin Elmer Elan 6000 as per USEPA 6020. The calibration range was set at 0.5 ppb to 20 ppb to meet very low level detections limits. The laboratory quality control samples and spike samples were analysed at 10 ppb level using ICP MS. The instrument detection limit (IDL), method detection limit (MDL) and method validation data are described in Appendix C.

3. 1.5.8 Mercury Analysis

Mercury testing was carried out using Flow Injection Mercury analyzer (Perkin Elmer FIMS 400). Sample preparation was done in accordance with USEPA 7470A standard Method, cold-vapor atomic absorption technique that based on the absorption of radiation at 253.7-nm by mercury vapor (APHA 3112B). Samples were digested with potassium permanganate and potassium persulfate oxidation method. Then, the mercury in the digested samples were reduced to the elemental state and was aerated from solution in a closed system. The mercury vapor passed through a cell positioned in the light path of an atomic absorption spectrophotometer. Absorbance (peak height) was measured as a function of mercury. A calibration standard was prepared from a stock Standard solution of 1000 mg/l Mercuric Nitrate. The calibration range was 0.5 µg/l to 20 µg/l. Samples concentrations were computed against the calibration curve from automated computer data handling system. The laboratory quality control samples and the spike samples were analysed at 10 ppb level and detailed in Appendix B. The method detection limit and the method validation data are described in Appendix C

3. 1.5.9 Pesticides Analysis

Samples were analysed for pesticides using USEPA 3510C and USEPA 8270 analytical methods. The list of pesticide compound analysed are listed in Table 3-3.

Water samples were extracted by transferring 1 litre of sample into a separatory funnel and 1 ml of surrogate solution was added followed by extracting with 60 ml of methylene chloride solvent, the first at neutral pH and 2 portions of 60 ml methylene chloride CH_2Cl_2 (DCM) solvent at $pH < 2$. The resulting extracts were concentrated using Kuderna - Danish (K-D) apparatus to 1 ml for analysis using Gas Chromatograph Mass spectrometer (GC MS). GC MS (Agilent Model 7890) was used for analysis of pesticides compounds. HP 5 column was used in Gas chromatography Mass spectroscopy for effective separation of pesticides compounds. The extracts were divided into aliquots for analysis and e 25 ul of internal standard was added to the aliquot. HPLC grade Methylene chloride (Merck HPLC Grade) was used in extraction.

Table 3.3, list of pesticide compounds which have been analysed

No	Pesticides	Method reference
	Organochlorine Pesticides	USEPA 3510C, 8270 C
1	Alpha–BHC	USEPA 3510C, 8270 C
2	Beta & gamma–BHC	USEPA 3510C, 8270 C
3	Delta–BHC	USEPA 3510C, 8270 C
4	Heptachlor	USEPA 3510C, 8270 C
5	Aldrin	USEPA 3510C, 8270 C
6	Heptachlor epoxide	USEPA 3510C, 8270 C
7	Endosulfan 1	USEPA 3510C, 8270 C
8	4,4-DDE	USEPA 3510C, 8270 C
9	Dieldrin	USEPA 3510C, 8270 C
10	Endrin	USEPA 3510C, 8270 C
11	Endosulfan 2	USEPA 3510C, 8270 C
12	4,4’-DDD	USEPA 3510C, 8270 C
13	Endosulfan Sulfate	USEPA 3510C, 8270 C
14	4,4’-DDT	USEPA 3510C, 8270 C
15	Endrin Ketone	USEPA 3510C, 8270 C
16	Methoxychlor	USEPA 3510C, 8270 C
	Organophosphorus Pesticides	
17	Dichlorvos	USEPA 3510C, 8270 C
18	Dimethoate	USEPA 3510C, 8270 C
19	Diazinon	USEPA 3510C, 8270 C
20	Chlorpyrifos methyl	USEPA 3510C, 8270 C
21	Malathion	USEPA 3510C, 8270 C
22	Fenthion	USEPA 3510C, 8270 C
23	Chloropyrifos	USEPA 3510C, 8270 C
24	Pirimiphos ethyl	USEPA 3510C, 8270 C
25	Chlorfenvinphos–E	USEPA 3510C, 8270 C
26	Chlorfenvinphos–Z	USEPA 3510C, 8270 C
27	Prothiofos	USEPA 3510C, 8270 C
28	Ethion	USEPA 3510C, 8270 C

3. 1.5.10 Total bacterial Count and Ecoli

The measurement was based on membrane filtration method, i.e the sample was filtered through 0.45 µm membrane and incubated on selected agar medium at 35^{o} C for 24 - 48 hours in accordance with APHA, 21st edition 2005, method 9215D.

Calculation

$$\text{Total Aerobic Bacteria Count} = \frac{\text{Colonies counted}}{\text{Sample volume filtered}} \times 100$$

The results obtained were recorded as Total Bacteria Count per 100 ml sample

3.1.6 Quality Assurance /Quality Control in Water samples Analysis

3.1.6.1 Reagent Blanks

To confirm absence of background contamination at parts per billion levels, blanks were analyzed. Blanks were used to assess contamination caused by sample bottles, ultra pure water and reagents. Field blanks were also taken during biological and chemicals analysis sampling to characterize biological contaminants that might be retained and passed to the next sample (APHA 1020B, 2005). In the entire analysis the reagent blanks were prepared similar to the preparation of samples and the results obtained were below detection limits.

3.1.6.2 Method Detection Limits

Method detection was determined by preparing an analyte to the matrix of interest, to make a concentration near to the estimated method detection limit (MDL) (APHA 1040B, 2005). Method detection limit and method validation data are tabulated in Appendix C

3.1.6.3 Laboratory Fortified Blank (Lab Control sample)

Laboratory control sample to which a known concentration of the analyte of interest had been added. Laboratory controlled samples was used to evaluate the analysis performance and analyte recovery in reagent blank and the recoveries obtained are detailed in results (Appendix B) and discussion chapter.

3.1.6.4 Matrix Spike

Spiking of certain samples was performed as a quality assurance check when samples were analyzed in laboratory. This step was to verify consistency with the results and percent recovery.

3.1.6.5 Replicate Analysis

One sample in a batch was analyzed in duplicates at each sampling in order to have complete confidence that values detected were not anomalous. Relative standard deviations of duplicate results were within 15%.

3.2 Bioaccumulations of heavy metals in aquatic life at Sungai Pencala

When fishes are exposed to elevated levels of metal in an aquatic environment, they can absorb the bioavailable metals directly from the environment via the gills and skin or through the ingestion of contaminated water and food. Metals in the fish are then transported by the bloodstream which brings it into contact with the various organs and tissues (Vander Putte, 1982). Fish species usually accumulate small quantities of heavy metals, but predatory fishes sometimes accumulate greater quantities than the rest of aquatic organisms. (Svoiodov and Hejtmnek, 1985).

Plants readily assimilate through the roots such compounds, which dissolve in waters and occur in ionic forms. Additional sources of these elements for plants are: rainfall; atmospheric dusts; plant protection agents; and fertilizers, which could be adsorbed through the leaf blades (Lozak etal., 2001).

Five sampling points at Sungai Pencala were selected to conduct a study on Bioaccumulations of heavy metals in aquatic life of the river. The sampling points are shown in the Figure 4.1. Sungai Pencala is the main tributary of Sungai Klang.

3.2.1 Field Sample Collection

Selection of sampling site is dependant on the surrounding land use and the number of stream running out of the area. Samples may be taken from stream focusing on areas which seem to have higher possibility of pollution and contamination. Fish and plant samples were collected once a month for 2 months. Fish samples were collected at three locations, (Table 3-4). Plants samples were collected at five locations along Sungai Pencala, (Table 3-5)

Table 3.4 Sampling location for Fish samples

Locations ID	**Description**
W 1	Stream upon Bukit Kiara
W 2	After KLGCC before Rimba Kiara
W 12	Tributary from Sg Way (guinnes)

Table 3.5 Sampling location for Plants samples

Locations ID	Description
W 1	Stream upon Bukit Kiara
W 2	After KLGCC before Rimba Kiara
W 9	Tributary from Taman Aman
W 11	Tributary from Jln Templer/Tandang
W 12	Tributary from Sg Way (guinnes)

The sampling points are shown in Figure 3.1, Fish and plant samples were taken from selected sampling points along Sg. Pencala as mentioned above. The samples were analyzed for heavy metals (arsenic, mercury, cadmium, chromium, lead, and copper) using Inductively Coupled Plasma Mass Spectrometer (ICP AES) and Flow injection mercury analyzer (FIMS 400).

3.2.2 Sample Preservation, Handling, and Storage

Fish samples for heavy metal analysis were collected using fishing net. Plant samples were collected manually along the river bank. The samples were stored in plastic bags. Fish and plant were kept on ice (0^{o}C) immediately after sample collection.

3.2.3 Interferences and potential problems

There are two primary interferences or potential problems with fish tissue sampling.

These include cross-contamination between samples and improper sample collection.

- To avoid cross-contamination, equipment used for the removal of fish tissues was properly decontaminated between samples, such as knives used to filet fish. Processed fish specimens were stored in a double Ziploc bags.
- To avoid contamination during sample collection and other potential sources of chemical contamination with river soil and sediment (e.g. as may happen when a live fish is dropped during handling) fish samples were adequately rinsed with deionized water before packing into plastic bags.

3.2.4 Analysis of Fish and Plant Sample

The analysis involved two main steps namely sample pre-conditioning or digestion and analysis of the digested samples using Inductively Coupled Plasma Mass Spectrometer (Perkin Elmer 5300DV) and Flow Injection Mercury Analyzer (Perkin Elmer, FIMS 400). All samples were subjected to an appropriate dissolution step prior to analysis of heavy metals cadmium, chromium, lead, arsenic and mercury.

3. 2.4.1 Sample Preparation for ICP AES

Fish and plant samples were cut into small pieces and ground thoroughly to achieve homogeneity. Samples (1-2 g) were accurately weighed in digestion tubes. 10 ml of nitric acid was added to the digestion tube and it was left overnight till a reaction subsided. The following day the digestion vials were placed on a hot block and the temperature gradually raised to 110 ^{o}C and the content boiled gently for about 2 hours to reduce the volume to between 2 – 5 ml. The digests were allowed to cool and transferred to a 25 ml volumetric flask and made up to the mark with de-ionized water. The digests were kept in plastic bottles for heavy metals determination using ICP -AES.

3. 2.4.2 Sample Preparation for Mercury Analysis on FIMS

Fish and plant samples were cut into small pieces and ground well thoroughly to achieve homogeneity. Samples (1 – 2 g) were accurately weighed into digestion tubes. About 6 ml of an acid mixture in ratio 5:3:1 (nitric acid: perchloric acid: sulphuric acid) was added to the digestion vial and the vial was left overnight till reaction subsided. The next day digestion vials were placed on a hot block and the temperature gradually allowed raised to 95 ^{0}C and the content heated for about 2 hours to reduce the volume. The digests were allowed to cool and transferred to 25 ml volumetric flasks and made up to the mark with de-ionized water. The digests were kept in plastic bottles and analyzed on Flow Injection Mercury Analyzer (FIMS) for mercury (Perkin Elmer,FIMS 400).

3. 2.4.3 Heavy Metals Analysis on the Instruments

After the acid digestions, fish and plant samples were analyzed for cadmium, arsenic, chromium, cadmium, and lead using Inductively Coupled Plasma Mass Spectrometer (ICP-MS) while mercury was analyzed using Flow Injection Mercury Analyzer (FIMS). Digested sample analyses were carried out using Inductively Coupled Plasma Mass Spectrometer (ICP-MS) model Perkin Elmer Elan 6000 as per USEPA 6020 for cadmium, lead, arsenic and chromium analysis. The calibration range was set to 0.5 ppb to 20 ppb to meet very low level detections limits. Mercury testing was carried out using Flow Injection mercury analyzer Perkin Elmer FIMS 400, a cold-vapor atomic absorption technique which is based on the absorption of radiation at 253.7-nm by mercury vapor (APHA 3112B). The digested samples were reduced to the elemental state and aerated from solution in a closed system. The mercury vapor passed through a cell positioned in the light path of an atomic absorption spectrophotometer. Absorbance (peak height) was measured as a function of mercury. The calibration standard was prepared from NIST stock Standard of 1000 mg/l mercury nitrate. Calibration range was 0.5 μg/l to 20 μg/l.

3. 2.4.4 Calculation of Heavy Metals Content

Sample concentrations were calculated as follows, mg/kg

$$= \frac{F \times (C - B)}{M} \times V \quad \text{mg/kg}$$

Where:

C = Sample concentration obtained from ICP-AES (mg/ L) or FIMA

B = Reagent blank solution concentration (mg/ L)

M = Sample weight (g)

V = Volume of final solution (ml)

F = Dilution factor

3.2.5 Quality Control and Assurance for analyzing Fish& plant samples

3.2.5.1 Reagent Blanks

To confirm absence of background contamination at parts per billion levels, blanks were analysed. Blanks were prepared by adding the same amount reagents added into the samples to the de ionized water, digested , analysed along with sample batch and the results used to assess background contamination caused by reagents and containers that are used for the analysis. The reagent blanks results obtained were below detection limits.

3.2.5.2 Laboratory Fortified Blank

Laboratory control sample, to which a known concentration of the analyte of interest has been added to the same amount of reagents added to samples. Laboratory controlled samples was used to evaluate the analysis performance and analyte recovery in reagent blank. Recoveries were found to be 84% to 106%.

3.2.5.3 Matrix Spike

Spiking of certain samples was performed as a quality assurance check when samples were analyzed in laboratory. This step was to verify consistency with the results and percent recovery.

3.2.5.4 Replicate Analysis

Samples were analyzed in duplicate at each station in order to have complete confidence that values detected were not anomalous.

3.2.5.5 Certified reference material

Certified reference material from National Research Council Canada, DOLT 2 was analyzed as a quality control sample.

Summary of quality control data are detailed in Appendix D

3.3 Characterization of solid waste

Solid waste comprise all the wastes arising from human and animal activities that are normally solid and that are discarded as useless or unwanted (Tchobanoglous, 1993). People throw things away when they do not have a use for them or think they have no obvious value. Garbage, refuse or other waste matter of a solid nature can be classified as solid waste. Solid waste is one of the by-products of human activities. The introduction of new materials, changing consumption patterns, and increasing waste generation, especially in urban areas, has contributed to the problems of waste management. These problems have escalated rapidly over the past few decades, while the government and people have failed to realize their serious implications and an urgent need to address them. Improper management of waste has led to environmental pollution, public health hazard, and adverse effects on an urban economy that depends heavily on tourism (Tchobanoglous, 1993).

Solid waste characterization means finding out how much paper, glass, food waste, etc. is discarded in waste stream (McCauley-Bell et al, 1997). Waste characterization information helps in planning how to reduce waste, set up recycling programs, and conserve money and resources. Waste characterization information is designed for solid waste planning; however, anyone interested in the characteristics of the solid waste stream may find it useful. Local government planners, haulers, and recyclers may estimate the amount of certain materials in their waste stream through the waste characterization data base. Waste characterization data is collected by taking samples of waste and sorting it into material types like newspaper and aluminum cans, and weighing each type (McCauley-Bell et al, 1997).

Solid waste according to Basel Convention is a substance or object which is disposed off or is intended for disposal or is required to be disposes off by the provisions of national laws (Basel Convention, 1989). Solid waste may disrupt river ecosystem in a way that may affect the aquatic life survival. Plastic waste for example which is the common waste found in Malaysia, can either be ingested by aquatic life, causing internal organ failure, or they can cause a slow strangulation. This may disrupt the food chain of the river ecosystem as a whole (Newton, 1990).

In view of these, the current study was undertaken to investigate the impact of solid waste on Sungai Pencala. Four sampling points at Sungai Pencala were selected in order to investigate the solid waste composition of the river in this study.

Sampling locations were selected based on the type of activity; easiness to collect the samples as well as safety reasons (Figure 3.1). These sampling points also represent the river's upstream, middle stream and downstream.

3.3.1 Selection of Sampling Site

Sampling points were identified based on the possible amount of solid waste and easiness to collect the sample. Solid waste samples and *in-situ* water quality data was collected once in a month.. The location of the sampling sites is shown in Table 3.6. Sampling was done by collecting a representative portion of solid waste at each sampling site. Before going to the field work, the necessary arrangements for sampling were made for. A sampling location map that labels the sampling site was prepared. A field data sheet was prepared to record specific information such as date and time of collection as well as weather conditions which will become important when interpreting data.

Table 3.6: Location of Sampling Site

Sampling Point	Location
W2	After KLGCC before Rimba Kiara
W9	Tributary from Taman Aman
W11	Tributary from Jln Templer/Tandang
W12	Tributary from Sg Way

3.3.2 Sample collection

For solid waste collection, the samples were collected for one hour at each sampling point using fishing net. Solid waste collected was segregated into different categories based on its physical nature. Solid wastes were categorized into paper and paperboard, plastics, organic waste, inorganic waste, metal, glass, household wastes, bulky objects and hazardous wastes. Total quantity of solid waste collected in one hour was determined using weighing scale on site and the percentage of each category of solid waste was calculated using the following calculation.

$$\text{Percentage of solid waste (\%)} = \frac{\text{Weight of solid waste of each type in g}}{\text{Total weight of solid wastes in g}} \times 100$$

Characterization of solid waste provides information on the major categories of solid waste at each sampling point. Consistency in the sampling method was maintained for essential statistical analysis of the collected data.

CHAPTER IV

RESULTS & DISCUSSION

4.1 Water Quality Studies

Water quality data was collected for a period of 16 months i.e. from March 2006 to June 2007. Refer Appendix C for the tabulated date, showing water quality analysis results with batch quality control data obtained for Sungai Pencala at 14 sampling stations

4.1.1 pH

pH represents the effective concentration of hydrogen ions (H^+) in water. This concentration could be expressed in the same unit as other dissolved species, but [H^+] are much smaller than other species in most waters. The pH values along the sampling points at Sungai Pencala for twelve months are shown in Figure3.1. The pH was high at sampling location W-11 in May, September and November 2006, pH value had suddenly increased in May 2006 which was from 6.51 at sampling point W-10 to 9.77 at sampling point W-11. In July 2006 pH had become normal i.e. 6.55 at sampling point W-11, In September, the pH value significantly increased to 8.12 and in November, 8.59 at sampling point W-11. The pH results are shown in Table 4.1

All pH measurements meet Interim National Water Quality Standard for Malaysia except at location W-11 which is mainly surrounded by industrial area. At this sampling point we were able to see visually the mixing of the waste discharge from the galvanising unit located nearby the sampling station. The lowest pH was observed at Sampling point W-1 at 5.77 in May 2006,in July 2006 at 5.34 and in June 2007 at 6.02. The pH ranges between 5.77 to 9.77

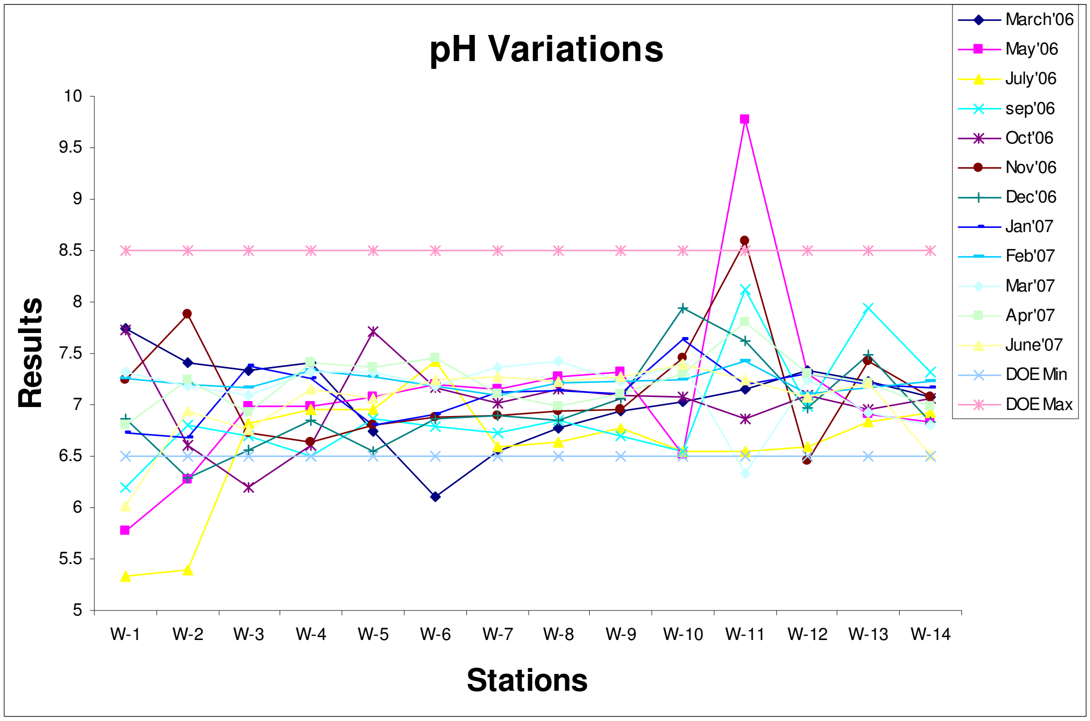


Figure 4.1 pH variation in Sungai Pencala between March 2006-June 2007

The pH of water determines the solubility and biological availability of chemical constituents such as nutrients and heavy metals, where the usage of nutrients by aquatic life is influenced by the pH of water. For heavy metals, it tends to be more toxic at lower pH because they are more soluble and more bioavailable (Horner et. al, 1990). As the pH falls (solution becomes more acidic) many insoluble substances become more soluble and thus available for absorption. One of the most significant environmental impacts of pH is the affect that it has on the solubility and thus the bioavailability of other substances. This process is important in surface waters. Runoff from agricultural, domestic, and industrial areas may contain iron, lead, chromium, ammonia, mercury or other elements.

Table 4-1 : pH data at Sungai Pencala sampling station from March 2006- June 2007

Locations	March'06	May'06	July'06	Sep'06	Oct'06	Nov'06	Dec'06	Jan'07	Feb'07	Mar'07	Apr'07	June'07
W-1	7.7	5.8	5.3	6.2	7.7	7.2	6.9	6.7	7.3	7.3	6.8	6.8
W-2	7.4	6.3	5.4	6.8	6.6	7.9	6.3	6.7	7.2	7.2	7.2	6.9
W-3	7.3	7.0	6.8	6.7	6.2	6.7	6.6	7.4	7.2	7.1	6.9	6.8
W-4	7.4	7.0	7.0	6.5	6.6	6.6	6.9	7.3	7.3	7.3	7.4	7.2
W-5	6.8	7.1	7.0	6.9	7.7	6.8	6.6	6.8	7.3	7.3	7.4	7.1
W-6	6.1	7.2	7.4	6.8	7.2	6.9	6.9	6.9	7.2	7.2	7.5	7.2
W-7	6.6	7.2	6.6	6.7	7.0	6.9	6.9	7.1	7.1	7.4	7.1	7.3
W-8	6.8	7.3	6.6	6.9	7.2	6.9	6.9	7.1	7.2	7.4	7.0	7.2
W-9	6.9	7.3	6.8	6.7	7.1	7.0	7.1	7.1	7.2	7.2	7.1	7.3
W-10	7.0	6.5	6.5	6.5	7.1	7.5	7.9	7.6	7.2	7.4	7.3	7.4
W-11	7.2	9.8	6.6	8.1	6.9	8.6	7.6	7.2	7.4	6.3	7.8	7.2
W-12	7.3	7.3	6.6	7.0	7.1	6.5	7.0	7.3	7.1	7.2	7.3	7.1
W-13	7.2	6.9	6.8	7.9	7.0	7.4	7.5	7.2	7.2	6.9	7.2	7.2
W-14	7.1	6.8	6.9	7.3	7.1	7.1	6.8	7.2	7.2	6.8	7.0	6.5

Fig 4.2 Sampling location W-11, Mixing of waste water from nearby Galvanizing Industry

From the results obtained, it shows that the pH of Sungai Pencala were nearly neutral with low salinity and under class I of DOE standard. Only a few points falls under class II such as at W-1 in May and July 2006 and W-11 in May, September and November 2006.

4.1.2 Temperature

The temperature of water is one of the most important characteristics that determines, to a considerable extent, the trends and tendencies of changes in the river water quality. Increased water temperature decreases the solubility of dissolved oxygen and water temperatures above 27^0C are “unsuitable” for public use. At above 32^0C it would be considered “unfit” for public use (Chapman, 1992). Temperature plays a vital part in chemical and biochemical reactions and is an important factor influencing self-purification in streams. The metabolic rate of aquatic organisms is related to water temperature, and in warm waters, respiration rates increase leading to increase oxygen consumption. Growth rate will also increases. This can lead to increased decomposition of organic matter, water turbidity, macrophyte growth and algal blooms, especially when nutrient conditions are suitable (Jackson and Jackson, 1996). Toxic chemicals made more soluble by higher temperature may present an additional hazard to the organisms in the water (USEPA, 1986). Higher temperature increases the toxicity of many substances such as heavy metals or pesticides, whilst the sensitivity of the organisms to toxic substances also increases. Increase in water temperature causes a decrease in oxygen solubility, an increase in the rate of biochemical oxygen demand (BOD) and in nitrification process. As a result, there may be oxygen deficiency and capacity of the receiving waters to assimilate waste is reduced.

Temperature of water is a very important factor for aquatic life. It controls the rate of metabolic and reproductive activities and determines which fish species can survive. It also affects the concentration of dissolved oxygen and can influence the activity of bacteria and toxic chemicals in water. Temperature affects the oxygen content of the water (oxygen levels become lower as temperature increases); the rate of photosynthesis by aquatic plants; the metabolic rates of aquatic organisms; and the sensitivity of organisms to toxic wastes, parasites, and diseases (EPA, 1997). Table 4.2 and Figure 4.3 show the temperature recorded at each sampling point during the study in Sungai pencala.

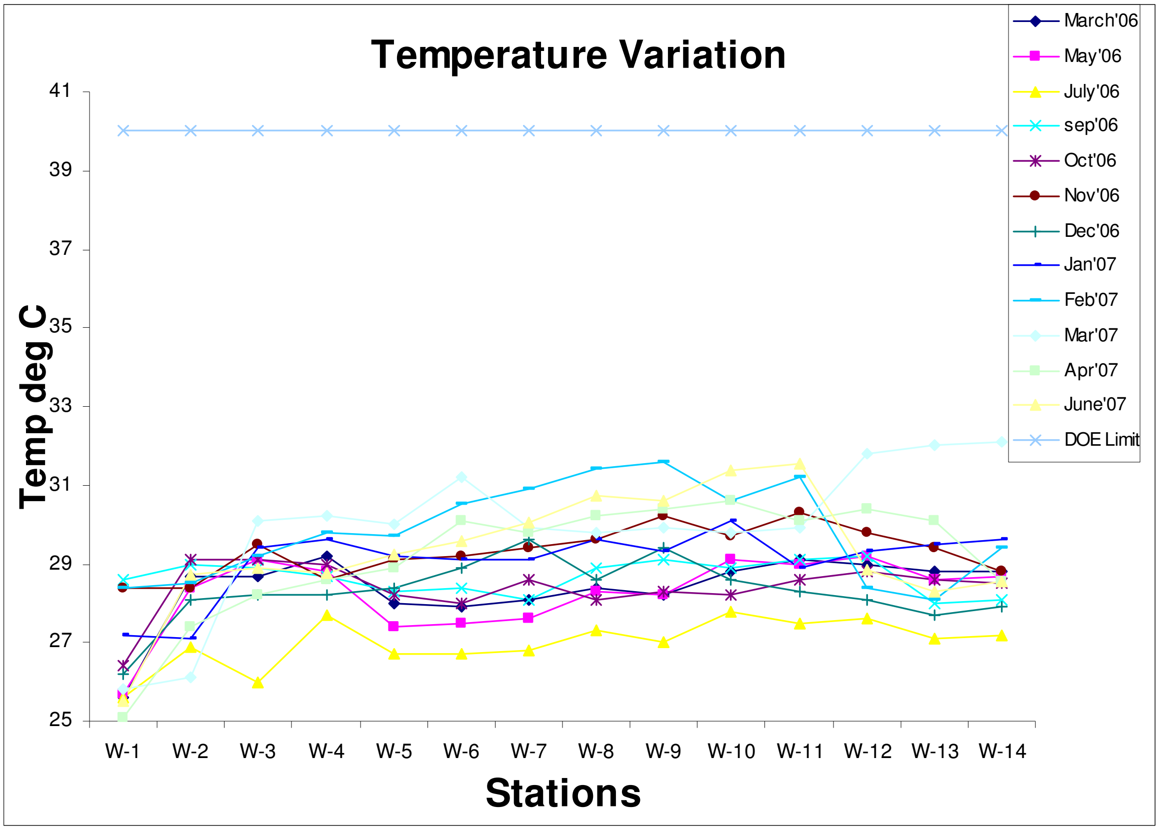


Figure 4.3 Trend of temperature data at sampling station from March 2006-June 2007

Figure 4.3 shows the trend of temperature at selected points along Sungai Pencala. Water temperature at upper stream was low, however when it flows along the middle stream and down stream the temperaure increased. The temperature ranged between 25.1 to 32.1^{o}C. All of the measured temperature meets the interim National Water Quality Standard for Malaysia

Table 4.2; Temperature Measurement data in Sungai Pencala at each site during March 2006- June 2007

Locations	March'06	May'06	July'06	Sep'06	Oct'06	Nov'06	Dec'06	Jan'07	Feb'07	Mar'07	Apr'07	June'07
W-1	25.6	25.7	25.6	28.6	26.4	28.4	26.2	27.2	28.4	25.8	25.1	25.5
W-2	28.7	28.4	26.9	29	29.1	28.4	28.1	27.1	28.5	26.1	27.4	28.7
W-3	28.7	29.1	26	28.9	29.1	29.5	28.2	29.4	29.2	30.1	28.2	28.9
W-4	29.2	28.8	27.7	28.7	29	28.6	28.2	29.6	29.8	30.2	28.6	28.8
W-5	28	27.4	26.7	28.3	28.2	29.1	28.4	29.2	29.7	30	28.9	29.2
W-6	27.9	27.5	26.7	28.4	28	29.2	28.9	29.1	30.5	31.2	30.1	29.6
W-7	28.1	27.6	26.8	28.1	28.6	29.4	29.6	29.1	30.9	29.9	29.8	30.0
W-8	28.4	28.3	27.3	28.9	28.1	29.6	28.6	29.6	31.4	29.8	30.2	30.7
W-9	28.2	28.2	27	29.1	28.3	30.2	29.4	29.3	31.6	29.9	30.4	30.6
W-10	28.8	29.1	27.8	28.9	28.2	29.7	28.6	30.1	30.6	29.8	30.6	31.4
W-11	29.1	29	27.5	29.1	28.6	30.3	28.3	28.9	31.2	29.9	30.1	31.5
W-12	29	29.2	27.6	29.2	28.8	29.8	28.1	29.3	28.4	31.8	30.4	28.9
W-13	28.8	28.6	27.1	28	28.6	29.4	27.7	29.5	28.1	32	30.1	28.3
W-14	28.8	28.7	27.2	28.1	28.5	28.8	27.9	29.6	29.4	32.1	28.54	28.5

The temperature showed a low value at sampling point W1 for each month. In April 2007, the lowest temperature was recorded at sampling point W-1 which was 25.1 ^{o}C. The highest temperature was recorded at point W-14 (32.1 ^{o}C). W-1 is located at Bukit Kiara where the Sungai Pencala originates and is a recreational area where activities like fishing or camping taking place, so, the temperature was lower because of its surrounding environment. W-14 is located near the highway and this factor had obviously caused a higher temperature at this point.

Temperature is important because it governs the kinds of aquatic life that can live in a stream. Fish, insects, zooplankton, phytoplankton, and other aquatic species all have a preferred temperature range. If temperatures get too far above or below this preferred range, the number of individuals of the species decreases until finally there are none. Temperature is also important because it influences water chemistry. The rate of chemical reactions generally increases at higher temperatures, which in turn affects biological activity. An important example of the effects of temperature on water chemistry is its impact on oxygen. Warm water holds less oxygen than cool water, so it may be "saturated" with oxygen but still not contain enough for survival of the aquatic life. Some compounds are also more toxic to aquatic life at higher temperatures. The thermal increase can be caused by the removal of trees and vegetation that shade and cool stream, (Bellos et al. 2005). Direct sunlight into the surface water was the contributing factor to high temperature as no filtering layer around the river bank. Waste heat can also affect the life in water and results in changing the composition and physiology of species. The temperature of Sungai Pencala based on these results showed that it is still below the Department of Environmental (DOE) standards. DOE standard for temperature of the stream is less than 40^{o}C. So, the temperature of Sungai Pencala falls in a good range under Class I.

4.1.3 Dissolved Oxygen

Dissolved oxygen measures the amount of gaseous oxygen (O_2) dissolved in an aqueous solution. Oxygen gets into water by diffusion from the surrounding air, by aeration (rapid movement), and as a product of photosynthesis. Adequate dissolved oxygen is necessary for good water quality. Oxygen is a necessary element to all forms of life. Natural stream purification processes require adequate oxygen levels in order to provide for aerobic life forms. As dissolved oxygen levels in water drop below 5.0 mg/l, aquatic life is put under stress. The lower the concentration, the greater the stress. Oxygen levels that remain below 1-2 mg/l for a few hours can result in large fish kills.

The fluctuations of Dissolved Oxygen (DO) in the surface water along the sampling points at Sungai Pencala for twelve months are shown in Table 4.3 and Figure 4.4. The first sampling point W-1 always showed the highest DO value, ranging between 6.0 to 7.79 mg/l. In March 2006 a very low DO value of 0.59 mg/l at sampling point W-3 which falls in the upstream area. This could be due to the activities at the commercial areas and wet market near this sampling point. Then the dissolved oxygen gradually increased at point W-4 and W-5 which was 5.28 mg/l and 5.36 mg/l, this could be due to mixing of treated water from Indah Water treatment plant located at sampling point W-5. The DO values started to decrease gradually from sampling point W-6 to W-14 as it flows through the commercial area and industrial area and the DO value was as low as 0.22 mg/l at sampling point W-14 which is at the extreme end of Sungai Pencala where it gets mix up the Klang river .

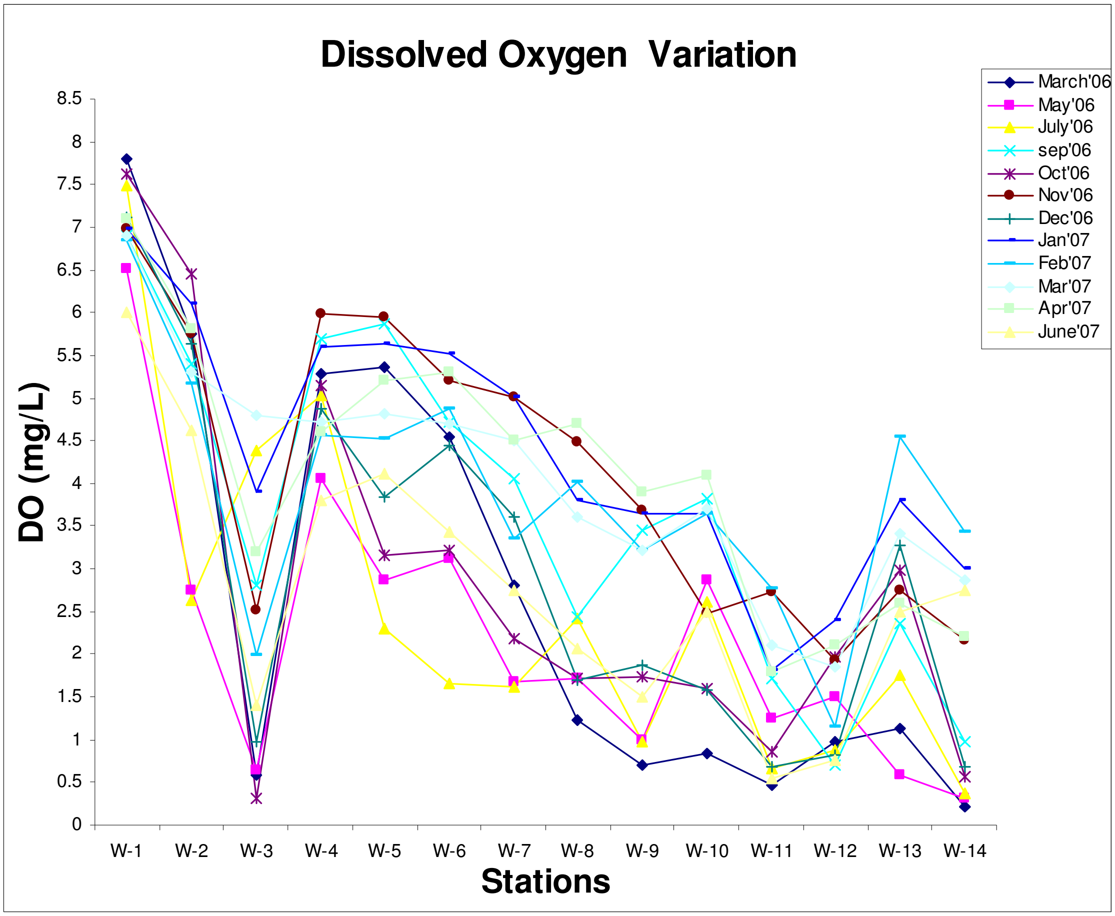


Figure 4.4 Trend of DO value at sampling station from March 2006-June 2007

Table 4-3; Dissolved Oxygen Measurement data in Sungai Pencala at each site during March 2006- June 2007

Loc	March'06	May'06	July'06	sep'06	Oct'06	Nov'06	Dec'06	Jan'07	Feb'07	Mar'07	Apr'07	June'07
W-1	7.79	6.52	7.48	6.90	7.63	6.98	7.12	6.98	6.84	6.90	7.10	6.00
W-2	5.75	2.75	2.64	5.40	6.45	5.76	5.64	6.11	5.16	5.30	5.80	4.62
W-3	0.59	0.64	4.38	2.80	0.31	2.51	0.98	3.90	1.98	4.80	3.20	1.40
W-4	5.28	4.05	5.03	5.70	5.15	5.98	4.88	5.60	4.57	4.72	4.60	3.80
W-5	5.36	2.86	2.31	5.86	3.15	5.94	3.84	5.64	4.53	4.81	5.20	4.12
W-6	4.55	3.11	1.66	4.71	3.21	5.21	4.44	5.52	4.87	4.70	5.30	3.44
W-7	2.81	1.67	1.62	4.06	2.19	5.01	3.60	5.01	3.36	4.50	4.50	2.74
W-8	1.23	1.72	2.42	2.43	1.71	4.48	1.70	3.81	4.02	3.60	4.70	2.06
W-9	0.71	0.99	0.98	3.45	1.73	3.68	1.88	3.64	3.21	3.21	3.90	1.50
W-10	0.84	2.87	2.61	3.83	1.60	2.48	1.57	3.64	3.64	3.70	4.10	2.50
W-11	0.46	1.24	0.67	1.71	0.86	2.72	0.69	1.81	2.76	2.10	1.80	0.55
W-12	0.97	1.51	0.88	0.71	1.96	1.93	0.81	2.40	1.15	1.86	2.10	0.77
W-13	1.14	0.58	1.75	2.35	2.98	2.74	3.28	3.81	4.55	3.42	2.60	2.50
W-14	0.22	0.32	0.37	0.97	0.56	2.16	0.68	3.01	3.43	2.86	2.20	2.75

In May, July, September, October, November, December, January, February 2006, the trend of DO was similar but there was slight increase in DO to 4.38 mg/l at point W-3 in July 2006. This could be due to the heavy rain before sampling. Then the DO value slightly increased to 5.03 mg/l at point W-4. Then again DO values started to decrease gradually from sampling location W-5 – W-14. Sampling location W-5 and W-6 are surrounded by residential and commercial area.

Fig 4.5 Sampling location W-6 where domestic waste discharges into Sungai Pencala

For March 2007, DO value decreased gradually from point W-1 at 6.9 mg/l to 4.81 mg/l at W-3. The same trend was maintained at all sampling locations upto W-7, there was a slight decrease to 3.6 at point W-8. Then there was a drastic decrease to 1.86 mg/l at point W-12 and slightly increase at point W-14 (2.86 mg/l). W-12 was located at residential area. During sampling it was observed that W- 12 had various type of solid waste found floating on the surface of the water. It was observed that the kitchen wastes like dead fish, and dead rat found floating on the surface of the river and this factor must have contributed to the lower level of DO value.

Almost similar trend of DO value was recorded in April 2007. At point W-1, the DO was detected at 7.1 mg/l. Then it decreased to 3.2 mg/l at point W-3. Low DO values were recorded at W-9, W-11 and W-12. The low concentration of DO in river may be affected by several processes such as respiration by aquatic organisms. Therefore, it is important to control the organic load into the water bodies as the abundance of organic pollutants could reduce DO concentration in water.

At W-3, which is located behind TTDI market, the waste from the wet market resulted in lower DO value of 3.2 mg/l. At W-4 after the Caltex petrol station, there is a slight increase in DO to about 4.6 mg/l due to treated water from Indah Water getting mixed up at this location and the same trend was maintained at W-5 to W-8 where these points are mainly surrounded by residential and commercial area. River water qualities at these locations are classified into Class III as per DOE standard. As the river flows through W-8, W-9, W-10, W-11, W-12, W-13, W-14 which are surrounded by Industrial areas the DO values constantly maintain very low DO values which falls under Class III of DOE standards. Figure 4.6, shows the pollution sources which caused low DO.

Figure 4.6 At sampling location W-14, wastewater discharge into river

Figure 4-7 Sampling location W-11 where industrial discharge gets mix up with stream water

Figure 4.7 shows location of W-11 tributary from Jln Templer/Tandang, which is surrounded by industrial area, and shows a wastewater discharge into the river from nearby industry. This had resulted in a low DO level of 1.8 mg/l. At W-12 Tributary from Sg Way (Guinness Malaysia) which is surrounded by residential area where domestic sewage and kitchen wastes are directly let into the river whereby organic pollution load increases resulting very low average DO value of 1.55 mg/l and falls under Class IV of DOE standard. At W-13 and W-14 there is a slight increase in DO results 3.57 and 3.0 mg/l respectively and it could be due to the dilution effect. W-13 and W-14 which are at the extreme end of down stream of the river and gets mix up with Klang river. Overall, the DO value of Sungai Pencala upstream W-2, W-4 falls under class III of DOE standard except W-1. Middle stream of the Sungai Pencala W-5, W-6, W-7, W-8 falls under class IV and class V. Down stream but some points falls under class IV (W-3, W-9, W-11, W-12).

Dissolved oxygen levels tend to have an inverse correlation with water temperature. Thus, dissolved oxygen levels were highest at the sampling location W-1. Dissolved oxygen levels were lower at W-2 & W-3 which fall in the upper region of the stream and there was slight elevation in dissolved oxygen results in the middle stream

The dissolved oxygen results decreased as it flows down stream. Low DO concentration had been reported at W-3, W-6, W-7, W-8, W-9, W-10, W-11, W-13, W-14. From the data of Mar'06 to June 07, for dissolved oxygen shows a continued problem, with Dissolved Oxygen values as low as 0.2 mg/l.

4.1.4 Conductivity

Conductivity is a measure of the ability of water to conduct an electrical current. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge). Conductivity is also affected by temperature: the warmer the water, the higher the conductivity. For this reason, conductivity is reported as conductivity at 25^0 C. Discharges to streams can change the conductivity depending on their make-up. A failing sewage system would raise the conductivity because of the presence of chloride, phosphate, and nitrate; an oil spill would lower the conductivity

Figure 4.8 and Table 4.4 show the conductivity along the sampling point at Sungai Pencala for a period of twelve months. The distribution of conductivity at Sungai Pencala showed the lower value at upstream and higher at downstream. Conductivity values were in the same trend throughout twelve months of monitoring. It increased gradually but substantial increase was observed at point W-10 and W-11 where there was a susceptible industrial pollution. In July 2006, the lowest was at point W-1 which was 25.8 µs/cm as this location is the origin of the river. The highest conductivity ie 965 µs/cm was detected at point W-3 as and it could be due to heavy building construction activities during sampling which caused higher influx of ions in the river. Except for this, the other results are meeting Interim National Water Quality Standard for Malaysia under Class II

Table 4-4; Conductivity (µs/cm)Measurement data in Sungai Pencala at each site during March 2006- June 2007

Locations	March'06	May'06	July'06	Sep'06	Oct'06	Nov'06	Dec'06	Jan'07	Feb'07	Mar'07	Apr'07	June'07
W-1	26.7	23.4	25.8	24.8	26.8	23.2	19.1	27.3	23.0	24.9	21.6	29.0
W-2	126.4	94.8	96.6	99.1	89.2	70.7	84.6	87.3	119.2	103.3	112.0	126.0
W-3	179.6	165.1	965.0	96.2	191.0	133.0	290.0	131.2	121.7	150.0	132.0	214.0
W-4	183.9	128.4	187.9	170.7	153.6	121.6	167.0	117.8	166.7	152.0	162.0	182.0
W-5	174.5	139.3	160.3	161.2	170.0	135.1	193.0	138.5	194.2	171.0	168.0	195.0
W-6	166.1	157.8	177.0	186.9	186.1	157.8	279.0	160.2	257.0	255.0	248.0	241.0
W-7	184.1	168.9	174.3	260.0	262.0	160.5	283.0	166.3	259.0	261.0	276.0	265.0
W-8	339.0	192.2	266.0	289.0	340.0	184.1	319.0	252.0	280.0	337.0	352.0	361.0
W-9	341.0	293.0	340.0	306.0	335.0	324.0	385.0	301.0	352.0	358.0	362.0	375.0
W-10	265.0	182.2	173.9	170.8	190.8	178.4	181.0	165.8	196.2	265.0	294.0	275.0
W-11	460.0	475.0	381.0	418.0	344.0	488.0	385.0	320.0	340.0	381.0	392.0	424.0
W-12	340.0	380.0	370.0	334.0	356.0	301.0	377.0	350.0	399.0	337.0	326.0	344.0
W-13	349.0	327.0	291.0	288.0	339.0	282.0	293.0	264.0	272.0	394.0	386.0	347.0
W-14	345.0	350.0	331.0	318.0	361.0	321.0	337.0	286.0	341.0	378.0	396.0	410.0

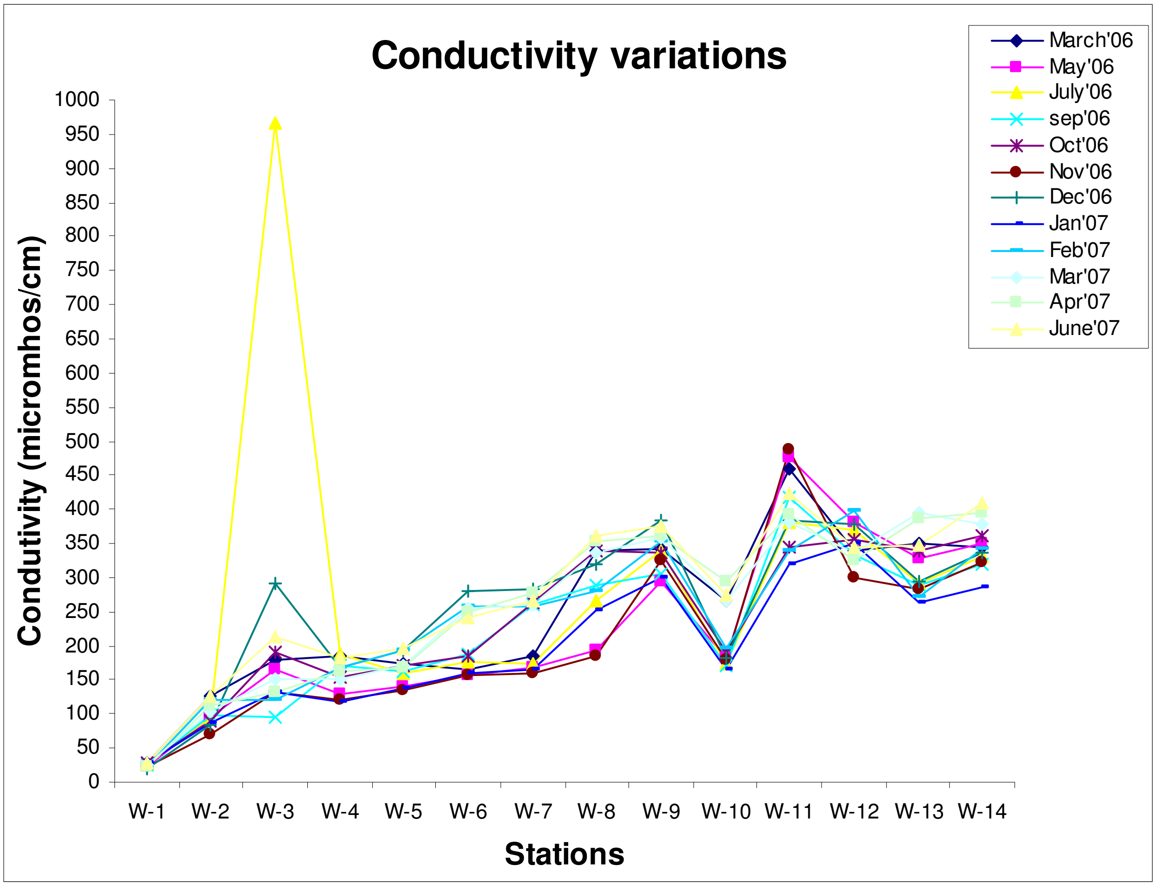


Figure 4.8 Trend in Conductivity data at sampling stations from March 2006-June 2007

In March 2006 sampling, the lowest conductivity of 26.7µs/cm was recorded at the first sampling location (W-1). As the water flows downstream, it increased gradually until at sampling location W-7, the reading was 184.1µs/cm. There was slightly higher conductivity results were observed at sampling location W-8 i.e. 339 µs/cm and the same trend was maintained at sampling location W-9. At sampling locations W-10, there was slightly lower conductivity was observed i.e. 265 µs/cm. After which the conductivity increased to up to 460 µs/cm at location W-11, which was the highest conductivity of this month reported at this sampling location. This is because of the industrial discharge from galvanising unit gets mixed up the stream. At sampling location W-12, it was observed that there is an Indah Water treatment plant which was not maintained properly resulting the waste water directly flow into the river stream resulting the conductivity to increase to 340 µs/cm. The same trend was observed at sampling location W-13 and W-14 which was surrounded by many industrial and commercial areas.

Figure 4.9 Industrial discharge gets mix up with stream at sampling location W-11

The rest of the data shows similar trend in the entire twelve months results. The conductivity of this Sungai Pencala during the four months duration of study falls under Class I of DOE standard where DOE standard is set to 1000 µs/cm

4.1.5 Total Dissolved solids

Total Dissolved solids also affect water clarity. Higher total dissolved solids decrease the passage of light through water, thereby slowing photosynthesis by aquatic plants. Water will heat up more rapidly and hold more heat; this, in turn, might adversely affect aquatic lives that are adapted to lower temperature regime. Total dissolved solids (TDS) comprise inorganic salts and small amounts of organic matter that are dissolved in water. The principal constituents are usually the cations such as calcium, magnesium, sodium and potassium and the anions such as carbonate, bicarbonate, chloride, sulphate and, particularly in groundwater.

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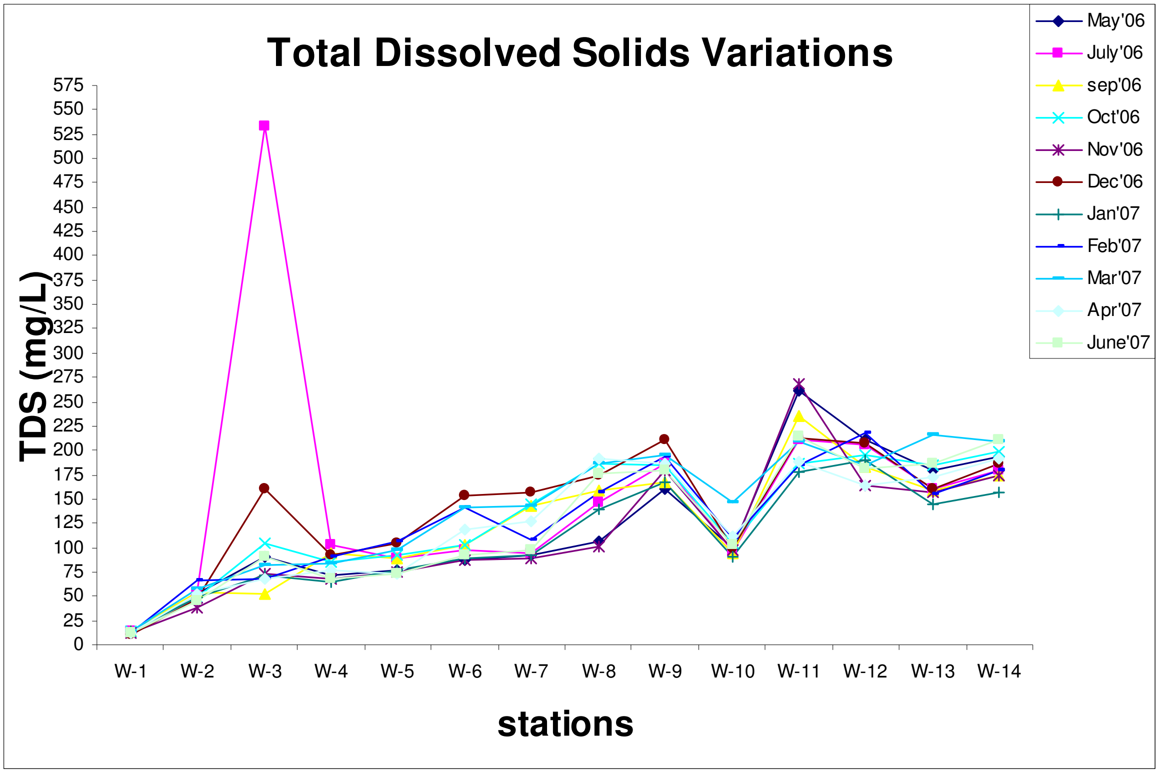

Figure 4.10 Trend in TDS data at sampling location from March 2006-June 2007

Table 4-5; Total Dissolved Solids in mg/l ; Laboratory Analysis data in Sungai Pencala at each site during March 2006- June 2007

Locations	March'06	May'06	July'06	Sep'06	Oct'06	Nov'06	Dec'06	Jan'07	Feb'07	Mar'07	Apr'07	June'07
W-1	14.5	12.8	14.0	13.7	14.6	12.8	10.1	14.6	12.6	13.5	12.0	13.0
W-2	69.5	52.2	53.6	54.0	49.1	39.0	46.6	48.1	65.5	57.0	52.0	46.0
W-3	98.2	90.6	533.0	53.0	104.0	73.2	160.0	72.2	67.1	82.5	68.0	90.2
W-4	102.0	71.0	102.0	94.1	84.6	67.1	92.0	64.7	91.2	83.8	76.0	67.7
W-5	95.8	76.5	89.5	88.8	92.4	74.3	105.0	75.9	107.0	98.0	74.0	72.9
W-6	92.8	86.9	97.2	103.0	103.0	86.8	154.0	88.2	142.0	141.0	118.0	93.0
W-7	101.0	92.9	94.3	143.0	144.0	88.5	156.0	91.5	108.0	143.0	128.0	98.3
W-8	187.0	106.0	147.0	158.0	187.0	101.0	174.0	139.0	156.0	186.0	192.0	176.0
W-9	186.0	161.0	187.0	168.0	184.0	179.0	211.0	167.0	193.0	196.0	186.0	180.0
W-10	145.0	100.0	96.4	93.8	105.0	97.6	99.7	90.6	109.0	146.0	112.0	103.0
W-11	253.0	261.0	211.0	236.0	187.0	269.0	213.0	177.0	185.0	209.0	188.0	215.0
W-12	188.0	210.0	205.0	183.0	196.0	163.0	208.0	190.0	217.0	185.0	164.0	181.0
W-13	189.0	179.0	161.0	158.0	184.0	157.0	161.0	145.0	155.0	216.0	172.0	187.0
W-14	189.0	193.0	180.0	174.0	199.0	175.0	186.0	156.0	179.0	209.0	192.0	211.0

Table 4-5 shows the amount of total dissolved solid (TDS) at Sungai Pencala for a period of twelve months. The TDS increases as the water flows to downstream. The lowest TDS reading of 10.1mg/l, was detected in December 2006 at point W-1 as this area was the source of the river and the water was clean and cold. The higher TDS was detected at point W-3 as 533mg/l and could be due to the heavy construction activities during July 2006 which took place nearby commercial area as well as the run off which always occured by the stream during rainy season.

Figure 4-10 shows the TDS variation during March 2006- June 2007. From the above figure it is clearly observed the same trend of TDS results have been obtained through out the monitoring except in July 2006. With reference to DOE standard, the total dissolved solids of Sungai Pencala, falls under Class I except in July 2006. In July 2006 stream falls under Class II of DOE standard.

4.1.6 Turbidity

Turbidity is a measure of the amount of particulate matter that is suspended in water. Water that has high turbidity appears cloudy or opaque. Turbidity is the condition that makes water cloudy and interferes with chlorination to eliminate contaminants. Turbidity will appear worse because of changing weather patterns and increasing runoff from land development upstate. Table 4.6 shows the variations of turbidity results variations in Sungai Pencala from the upstream to down stream. The sampling point W-3 located at the upstream region but the turbidity results showed very high due to wet market activities and construction activities near the sampling location. The river as it flows from the middle stream to down stream there is an increase in the turbidity results as shown in Figure 3-11. The turbidity results were very high due to heavy rain fall and run off.

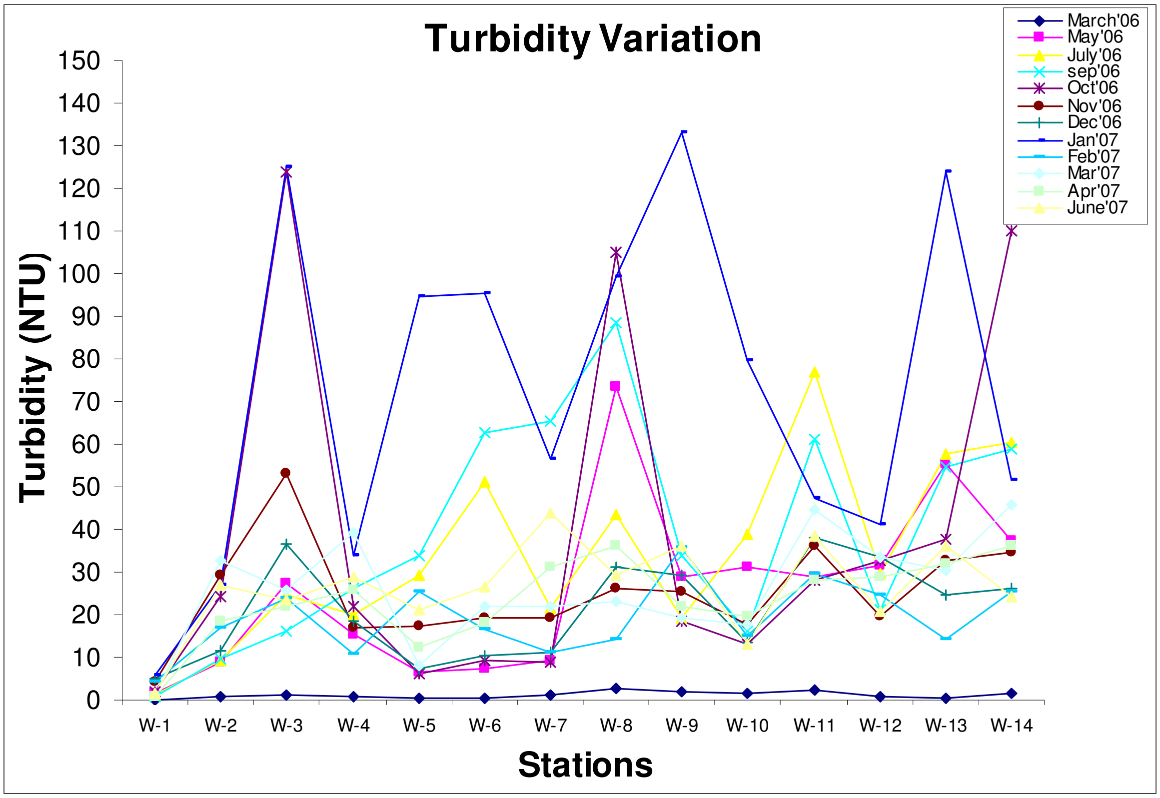

Figure 4-11 Total Dissolved Solids variation in Sungai Pencala , March 2006-June 2007

Table 4.6; Turbidity in NTU Measurement data in Sungai Pencala at each site during March 2006- June 2007

Loc	March'06	May'06	July'06	Sep'06	Oct'06	Nov'06	Dec'06	Jan'07	Feb'07	Mar'07	Apr'07	June'07
W-1	0.0	1.6	1.2	0.9	1.8	4.1	5.2	5.6	4.3	1.2	0.8	1.6
W-2	0.6	9.0	9.2	9.8	24.1	29.3	11.6	26.8	16.9	32.7	18.6	26.8
W-3	1.2	27.2	24.8	16.2	124.0	53.2	36.4	125.0	23.8	25.6	22.1	23.6
W-4	0.8	15.3	19.8	26.0	21.9	17.0	18.6	33.7	10.9	39.3	25.6	29.0
W-5	0.2	6.7	29.2	33.7	6.3	17.3	7.4	94.5	25.5	7.9	12.4	21.0
W-6	0.4	7.4	51.1	62.6	9.4	19.4	10.4	95.5	16.4	21.9	18.2	26.4
W-7	1.1	9.1	21.7	65.5	8.8	19.4	11.2	56.7	11.1	22.1	31.0	44.0
W-8	2.6	73.3	43.4	88.3	105.0	26.0	31.2	99.1	14.4	23.1	36.0	29.2
W-9	1.8	29.0	19.1	33.8	18.5	25.4	29.3	133.0	35.6	19.4	22.0	36.3
W-10	1.6	31.0	38.8	16.1	13.2	17.8	13.5	79.8	14.9	17.8	19.8	13.1
W-11	2.3	28.8	77.1	61.2	28.2	36.0	38.1	47.4	29.5	44.8	28.0	38.6
W-12	0.9	31.5	29.8	21.2	32.8	19.6	33.3	41.0	24.5	33.3	29.0	20.8
W-13	0.4	55.5	57.6	54.8	37.8	32.6	24.6	124.0	14.4	30.2	32.0	36.0
W-14	1.7	37.4	60.4	58.9	110.0	34.8	26.1	51.7	25.4	45.7	36.0	24.1

Table 4.6 shows the summary of turbidity results along Sungai Pencala. Figure 4.11 shows the fluctuation of turbidity at every sampling point at Sungai Pencala for the twelve months of sampling. The highest turbidity was recorded in January 2007. The highest turbidity was reported at point W-9 with a value of 133 NTU which could be due to the construction activity taking place nearby this sampling location as well as runoff due to heavy rain fall. At initial point, the turbidity was found to be in the range of 0 – 0.8 NTU. Then it drastically increased at point W-3 with 125 NTU in January 2007. Turbidity was noted to decrease at point W-4 with a value of 33.7 NTU then increased to 94.5 at point W-5. Point W-5 was located beside a residential area where wastewater from the houses was observed to get through a pipeline into the stream directly.

Figure 4-12: Pipe from houses directly routed to the stream at point W-9.

As river flows to middle stream and downstream, the turbidity reading increased due to sewage discharge, wastewater discharge from the industries and run off from heavy rain fall. At point W-1, the turbidity falls under class I of DOE standard as this location is the source point. But all the other locations were under class III. All the turbidity data from each point seems to have exceeded the DOE standard.

4.1.7 Chemical Oxygen Demand

Chemical Oxygen Demand is a vital test for assessing the quality of effluents and waste waters prior to discharge. The Chemical Oxygen Demand (COD) test predicts the oxygen requirement of the effluent and is used for monitoring and control of discharges, and for assessing treatment plant performance. Biochemical oxygen demand only measures the amount of oxygen consumed by microbial oxidation and is most relevant to waters rich in organic matter. It is important to understand that COD and BOD do not necessarily measure the same types of oxygen consumption. For example, COD does not measure the oxygen-consuming potential associated with certain dissolved organic compounds such as acetate. The impact of an effluent on the receiving water is predicted by its oxygen demand. This is because the removal of oxygen from the natural water reduces its ability to sustain aquatic life.

The trends in Chemical Oxygen Demand (COD) for the twelve months of sampling at Sungai Pencala are shown in Table 3.8 and Figure 3.13. In March 2006, at first sampling point W-1, COD was found to be 4 mg/l as this location while is the source point of the river and no pollution sources were found and the water was clean. The increased in COD value to 353.9 at point W-3 could be due to the heavy wet market activity nearby. A reduction of COD to 48 mg/l was observed at point W-4 where at this location treated water from Indah Water gets mixed up and diluted. Then, the COD gradually increased at point W-5 to W-9 within the range of 32 mg/l and 398 mg/l.

Table 4-7; Chemical Oxygen Demand, mg/l - Laboratory Analysis data in Sungai Pencala at each site during March 2006- June 2007

Locations	March'06	May'06	July'06	Sep'06	Oct'06	Nov'06	Dec'06	Jan'07	Feb'07	Mar'07	Apr'07	June'07
W-1	4.0	4.0	9.3	6.0	7.3	12.0	21.0	1.0	1.0	9.8	10.0	6.0
W-2	13.2	15.5	19.5	21.0	12.8	15.4	20.3	2.7	5.8	11.0	18.0	10.1
W-3	353.9	357.0	22.0	62.0	172.0	48.8	225.8	62.6	126.0	52.0	86.0	68.0
W-4	48.0	149.0	21.6	24.0	27.6	19.9	85.9	8.6	23.0	22.0	42.0	24.0
W-5	32.0	26.0	67.1	53.2	32.0	15.0	17.6	14.1	29.8	30.0	54.0	27.2
W-6	27.0	50.0	108.8	57.8	17.5	20.0	42.6	17.2	46.6	32.0	84.0	25.2
W-7	292.0	57.0	52.4	74.3	24.2	23.8	31.2	10.3	30.0	28.0	58.0	34.6
W-8	312.0	61.0	92.3	85.1	57.6	29.5	88.9	33.9	45.2	48.0	42.0	36.0
W-9	398.0	209.0	71.5	66.9	53.8	35.4	75.5	42.2	54.6	39.0	52.0	44.0
W-10	386.0	388.0	66.2	45.4	98.0	46.2	86.0	28.6	74.2	43.0	76.0	60.0
W-11	401.0	409.0	299.5	216.0	283.5	83.2	93.8	39.7	68.8	240.0	132.0	110.0
W-12	256.0	161.0	108.1	146.3	118.5	45.1	153.8	101.4	66.1	79.7	92.0	77.2
W-13	320.0	358.0	86.0	62.6	47.4	36.0	82.0	34.6	42.2	64.0	89.0	54.0
W-14	246.0	340.0	94.3	83.1	185.0	32.1	80.6	41.2	41.6	85.9	106.0	36.0

Similar trend was observed at W-10 and W-11. At sampling point W-12, COD value was slightly reduced to 256 mg/l. This location is surrounded by residential and commercial area and domestic waste was directly let into river stream. It also could have been caused by the untreated sewage that was discharged into the river from Indah Water Wastewater Treatment Plant. At W-1 and W-2 sampling locations there was no fluctuation observed in twelve months. At sampling location W-3 it is observed that in March 2006 and April 2006, COD results were very high at 353.9 and 357 mg/l but in July 2006 suddenly reduced to 21.97 mg/l which could be due to heavy rain fall. Again there was a slight increase in COD value to 62 mg/l in September 2006 and 172 mg/l in October 2006. Again the COD results reduced to 48.8 mg/l in November 2006 and went up to 225.8 in December 2006. There was slight reduction to 62.6 mg/l in January 2007 and increased to 126 mg/l in February 2007. Similar trend had been observed in March, April and June 2007 i.e. 52, 86 and 68 mg/l respectively.

At W-4 similar trend was observed in the entire monitoring period from March 2006 – June 2007 as in Table 3-7, except in May 2006 as 149 mg/l and December 2006 as 85.9 mg/l which could be over flow from sampling point W-3 where high sources of pollution wet market due to wet market activities. At sampling location which is surrounded by residential area W-5, there were not many fluctuations observed except in July 2006 where COD value reported as 67.1 mg/l. At sampling location W-6 also there were not many fluctuations observed except in July 2006 COD value reported as 108.78 mg/l. At sampling location W-7 which is surrounded by industrial area, the COD value was found very high in March 2006 at 292 mg/l and later it gradually reduced and maintained similar trend through out the twelve months.

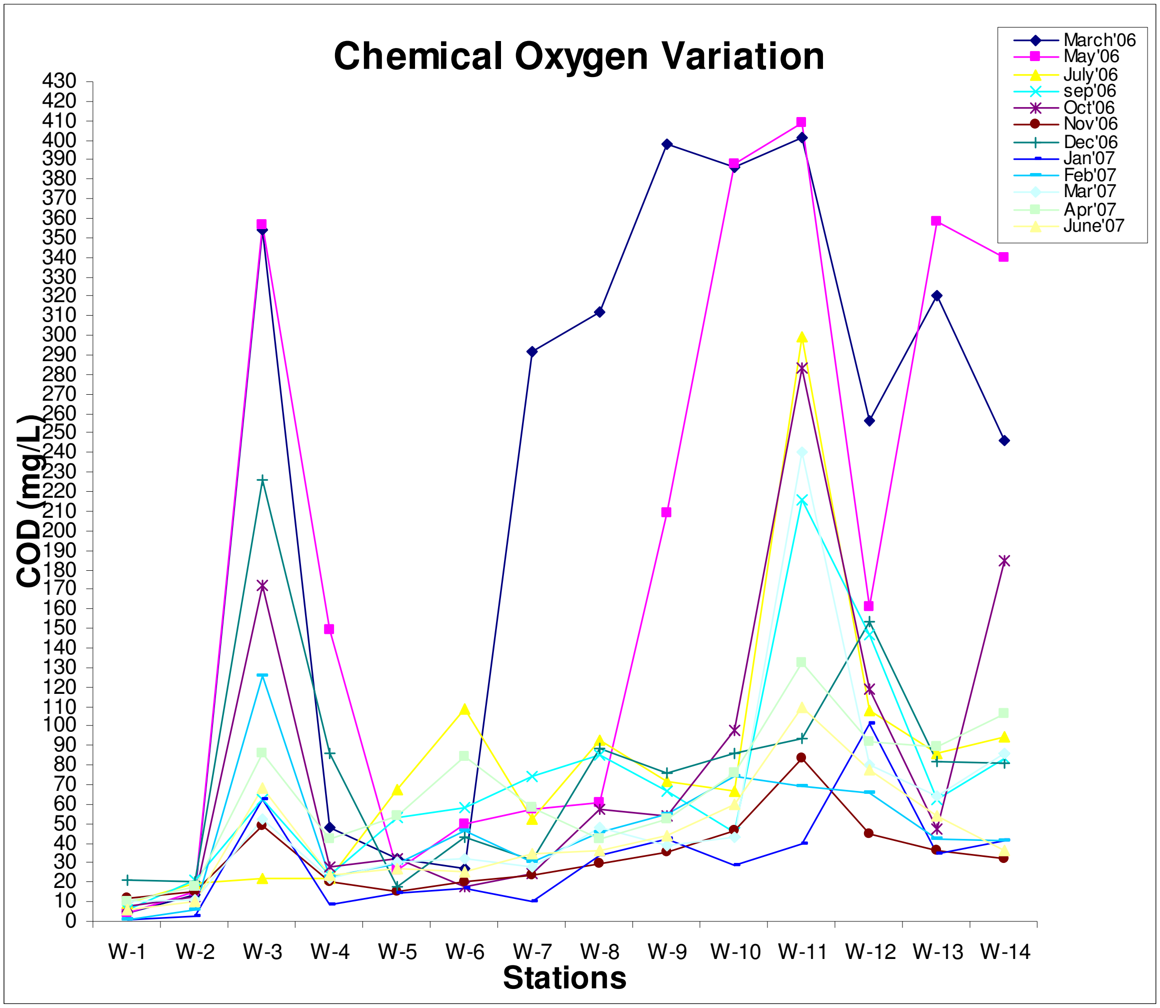

Figure 4.13 Trend in COD data at all sampling points from March 2006-June 2007

Sampling points W-8 and W-9 are surrounded by residential and commercial area. In March 2006 the COD values were found to be very high as 312 and 398 mg/l respectively which could be due to sewage discharge from the surrounding residential and commercial area and gradually started decreased and maintained similar trend in the entire study. Sampling locations W-10 and W-11 are surrounded by industrial area, very high COD values were observed i.e. 386 and 401 mg/l respectively in March 2006. But there was a slight increase in COD value from sampling point W-9 to W-10 and the same trend was maintained until W-14 which clearly indicates that high pollution sources towards down stream. A very high COD values was obtained at W-11 in March 2006 and April 2006 i.e.

401 and 409 mg/l respectively and gradually decreased from September 2006 to June 2007. This location is surrounded by many industries where we observed discharge of industrial wastes directly into the stream. At sampling location W-12 where many household wastes and kitchen wastes are directly let in to the stream and the COD values found to be high and maintained similar trends except in March 2006. The similar trends were observed for sampling location W-13 and W-14, which are at the extreme end of the Sungai Pencala surrounded by industrial and commercial area. Most of the sampling locations of Sungai Pencala fall under Class III of DOE standard for water quality. Some of sampling points such as tributary from Jalan Templer and tributary from Sg Way falls under Class V.

4.1.8 Biological Oxygen Demand

Biochemical Oxygen Demand, or BOD, is a measure of the quantity of oxygen consumed by microorganisms during the decomposition of organic matter. BOD is the most commonly used parameter for determining the oxygen demand on the receiving water of a municipal or industrial discharge. BOD is an indirect measure of biodegradable organic compounds in water. The stream system produces as well as consumes oxygen. It gains oxygen from the atmosphere and from plants as a result of photosynthesis. Running water, because of its churning, dissolves more oxygen than still water, such as that in a reservoir behind a dam. Respiration by aquatic animals, decomposition, and various chemical reactions consume oxygen.

Table 4.8; Biological Oxygen Demand in mg/l -Laboratory Analysis data in Sungai Pencala at each site during March 2006- June 2007

Locations	March'06	May'06	July'06	Sep'06	Oct'06	Nov'06	Dec'06	Jan'07	Feb'07	Mar'07	Apr'07	June'07
W-1	1	1	1	1	1	1	1	1	1	1	1	1
W-2	8	6	5	2	4	1	4	1	1	5	2	2
W-3	202	148	6	25	45	40	57	26	37	24	58	39
W-4	15	52	8	11	6	4	46	5	9	6	18	6
W-5	8	9	28	12	5	4	3	4	8	7	21	9
W-6	5	12	34	12	8	5	5	4	11	13	34	12
W-7	126	26	14	34	9	4	5	14	18	10	24	16
W-8	123	33	30	48	25	4	19	8	12	18	18	15
W-9	260	83	26	24	26	11	36	13	18	17	36	15
W-10	186	278	27	10	35	14	23	11	18	53	42	14
W-11	183	286	40	89	59	42	28	11	29	92	68	25
W-12	96	68	56	35	45	19	49	38	30	28	36	32
W-13	122	172	42	21	19	10	24	15	12	24	58	19
W-14	76	137	50	27	38	18	18	11	14	37	62	15

Wastewater from sewage treatment plants often contains organic materials that are decomposed by microorganisms, which use oxygen in the process. The amount of oxygen consumed by these organisms in breaking down the waste is known as the biochemical oxygen demand or BOD. Other sources of oxygen-consuming waste include storm water runoff from farmland or urban streets, feedlots, and failing septic systems.

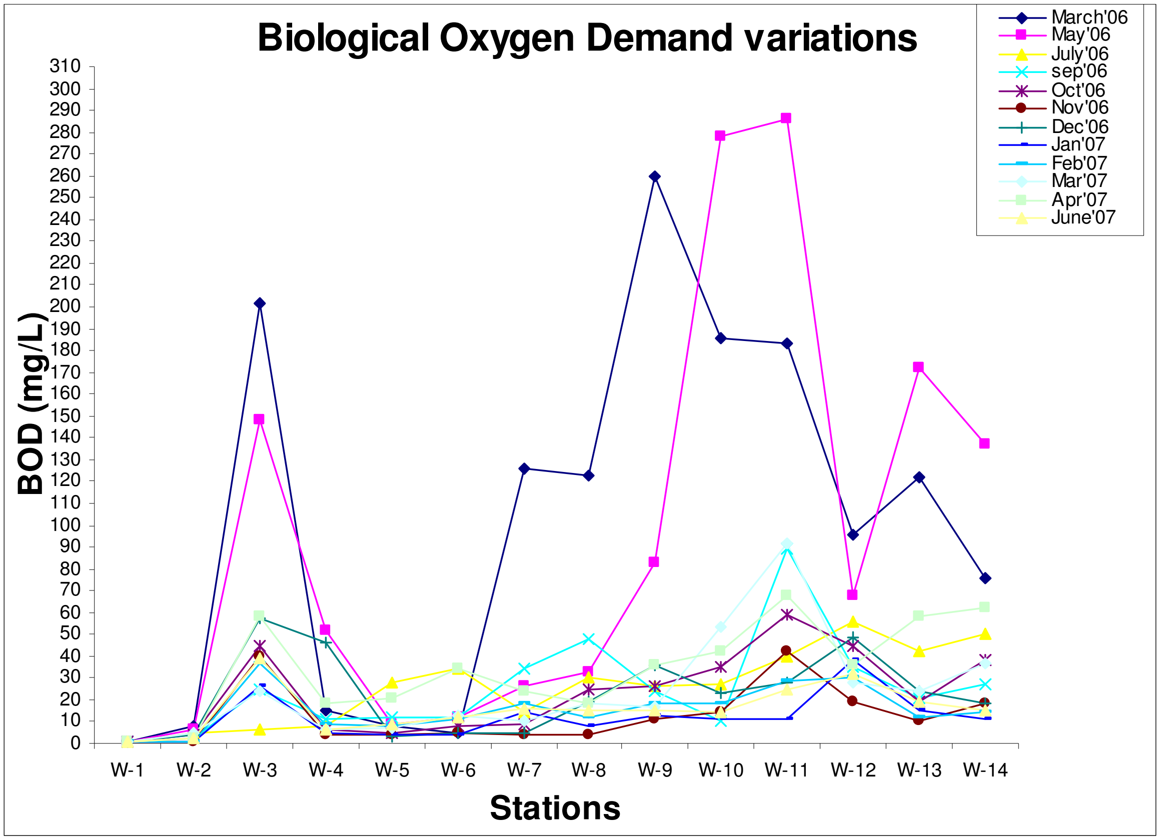

Figure 4.14 Trend in BOD data at sampling points from March 2006-June 2007

As seen in Figure 4-14, low Biological Oxygen Demand results were reported at upstream except for Location W-3, as it comes to the middle stream the BOD results were higher and again decreased when it flows down stream.

In March 2006, the lowest BOD value was detected at point W-1 and W-2 with the value of 1 mg/l and 8 mg/l respectively (Table 4.8 and Figure 4.14) while the highest was at point W-3 with a value of 202 mg/l. This is because of the wet market activities near this sampling location as discussed in COD results. Sampling points W-4, W-5 and W-6 were lower and again from W-7 the BOD values increased and shows similar trend until W-14. In March and May 2006 the BOD results were higher compared to other months. This is because of sewage from Indah Water Wastewater Treatment Plant at W-12 and also the domestic waste and organic waste such as dead rat and fish. Higher amount of oxygen was consumed by organism to break down the wastes. From July 2006- June 2007 similar trends were observed at all locations. At initial point, the stream falls under class II in terms of Biochemical Oxygen Demand. Some of the locations fall under class II and class III where at mid stream or towards the end down stream of the river falls under class V.

4.1.9 Ammoniacal Nitrogen

Nitrogen is required by all organisms for the basic processes of life to make proteins, to grow and to reproduce. Nitrogen is found in many forms in the environment. Inorganic forms include nitrate (NO_3), nitrite (NO_2), ammonia (NH_3) and nitrogen gas (N_2). The sources of the nitrogen into the river water are mainly by wastewater and septic system effluent, fertilizer runoff, animal waste, fossil fuels and also industrial discharge (Tilton, 1979). Nitrogen uptake is most effective where water flows slowly and evenly over the wetland surface thus providing an increase in the effective area and detention time available for biological interactions (Simpson, 1978; Tilton, 1979). Humans add excessive amounts of plant nutrients (primarily phosphorus, nitrogen, and carbon) to streams and lakes in various ways. Runoff from agricultural fields, field lots, urban lawns, and golf courses is one source of these nutrients. Untreated, or partially-treated, domestic sewage is another major source. Sewage was a particular source of phosphorus to lakes when detergents contained large amounts of phosphates. Ammoniacal nitrogen, NH_3-N is the measure of total nitrogen in water which is produce during oxidation process in the water. Ammonia maybe present as a gaseous (NH_3) or ammonium ion (NH_4^+) depending on pH.

Table 4-9, and Figure 4.15 shows the trends of ammoniacal nitrogen (NH_3-N) for twelve months sampling at Sungai Pencala. In January 2007, the lowest value of NH_3N was detected at all sampling locations could be due to the heavy rain fall that dilutes the nutrient in the water stream and was not detected at low levels . The higher NH_3-N value was reported at W-14 with the value of 9.45 mg/l in December 2006. As the water flows to downstream, the amount of NH_3-N increased due to the sewage discharged into the river from surrounding area. Surface runoff also caused the NH_3-N to increase. The value ranged from as low as near the detection limit to 14.2 mg/l in December 2006 at W-9. Ammoniacal nitrogen levels reported low in the upper stream and as it flows towards down stream the values increased.

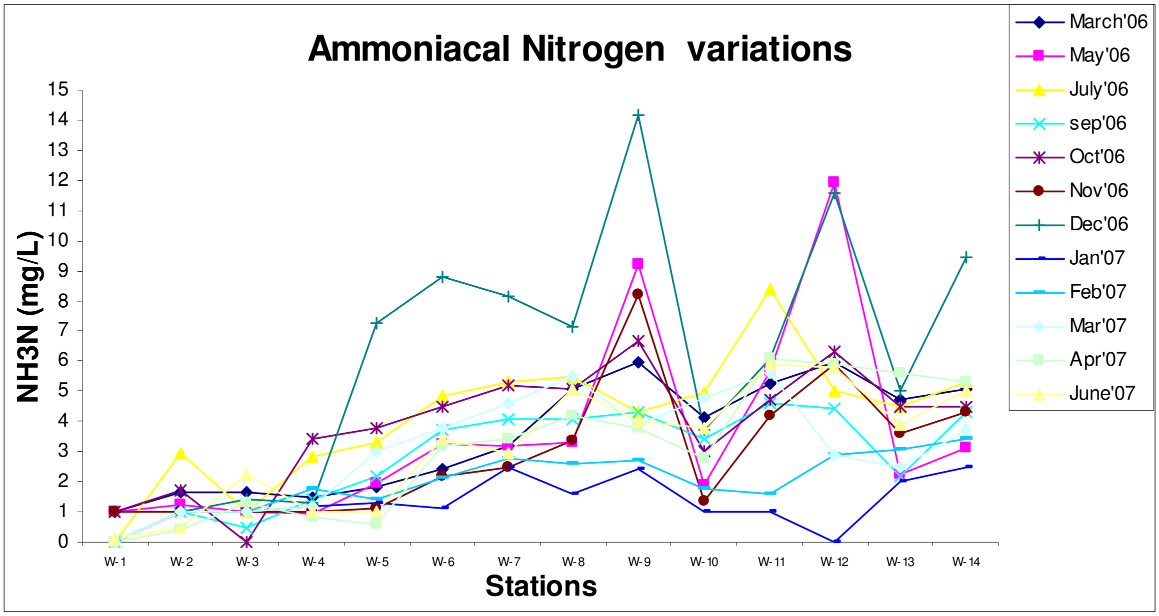

Figure 4.15 The trend in NH_3N at sampling points from March 2006-June 2007

Table 4-9; Ammonia Nitrogen in mg/L ; Laboratory Analysis data in Sungai Pencala at each site during March 2006- June 2007

Location	March'06	May'06	July'06	Sep'06	Oct'06	Nov'06	Dec'06	Jan'07	Feb'07	Mar'07	Apr'07	June'07
W-1	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.10
W-2	1.65	1.26	2.93	1.00	1.74	1.00	1.00	1.00	1.00	1.00	0.40	0.50
W-3	1.64	1.00	1.02	0.50	0.00	1.00	1.40	1.00	1.00	1.00	1.30	2.26
W-4	1.48	0.97	2.85	1.40	3.40	1.00	1.30	1.20	1.80	1.20	0.80	1.00
W-5	1.84	1.96	3.33	2.20	3.80	1.10	7.25	1.30	1.40	3.00	0.60	1.00
W-6	2.40	3.24	4.86	3.70	4.50	2.20	8.77	1.10	2.10	3.80	3.20	3.40
W-7	3.16	3.19	5.30	4.10	5.20	2.50	8.17	2.50	2.80	4.60	3.40	2.98
W-8	5.10	3.29	5.48	4.10	5.10	3.37	7.13	1.60	2.60	5.50	4.20	5.10
W-9	5.98	9.22	4.31	4.30	6.70	8.21	14.20	2.40	2.70	3.90	3.80	3.99
W-10	4.12	1.89	4.98	3.40	3.00	1.38	3.70	1.00	1.80	4.80	2.80	3.80
W-11	5.27	5.67	8.40	4.60	4.70	4.22	6.06	1.00	1.60	5.60	6.10	5.90
W-12	5.98	11.93	5.00	4.40	6.30	5.90	11.60	0.00	2.90	2.90	5.90	5.80
W-13	4.73	2.27	4.50	2.20	4.50	3.60	5.00	2.00	3.10	2.50	5.60	3.90
W-14	5.08	3.12	5.30	4.30	4.50	4.30	9.45	2.50	3.40	3.70	5.30	5.00

In March 2006, ammoniacal nitrogen was detected at very low level at W-1 and W-2 where there are no sources of pollution from sewage or waste water. As the river flows to middle stream and down stream there are many pollution sources from surrounding areas and discharge of waste water causes the results to be high. The highest results were reported at W-9 i.e. 6.0 mg/l. This sampling point is located near residential and commercial area. The discharge of sewage from the residents caused the amount of nutrient to be high.

It is observed that similar trend has been observed at sampling locations W-8 to W-14 in twelve months data in the range between 1 mg/l and 14.2 mg/l, except in January 2007 and February 2007. Sungai Pencala falls under class IV as per DOE standard for ammoniacal nitrogen.

4.1.10 Total Suspended Solids

Total suspended solids (TSS) represents the amount of filterable particulate material in water, expressed as mg/L. In general, the concentration of TSS increases with increasing river flow. Higher flows may result in increased sediment suspension or may reflect periods of runoff, both of which would contribute to higher TSS concentrations. In particular, runoff from watersheds with a predominance of cultivated lands is an important source of suspended matter in the river. In addition, stream bank erosion in many tributaries can contribute to large loading of TSS to the river during high flow events. Once TSS has reached the river, the particulate material may contribute to sedimentation problems in backwaters, negatively influence submerged aquatic plant growth due to decreased light penetration, smother benthic invertebrates, and lead to other impairments (USEPA 2002).

Table 4.10 shows the total suspended solid (mg/l) from March 2006 to June 2007. Total suspended solids ranged from 1.0 mg/L to 141 mg/L between March 2006 and June 2007. The very high suspended solids concentrations in Sungai Pencala reported in March 2006 at W-8 near the industrial area i.e. 141 mg/l. Generally, concentrations of total suspended solids do not significantly differ from sites in the up stream of the river to down stream however; levels significantly increase after heavy rain fall run off. There were significantly high suspended solids reported in May 2006 and January 2007 at all sampling location. The rest of the sampling data shows the similar trend for total suspended solids results. Sungai Pencala falls under class III as per DOE standard for suspended solids.

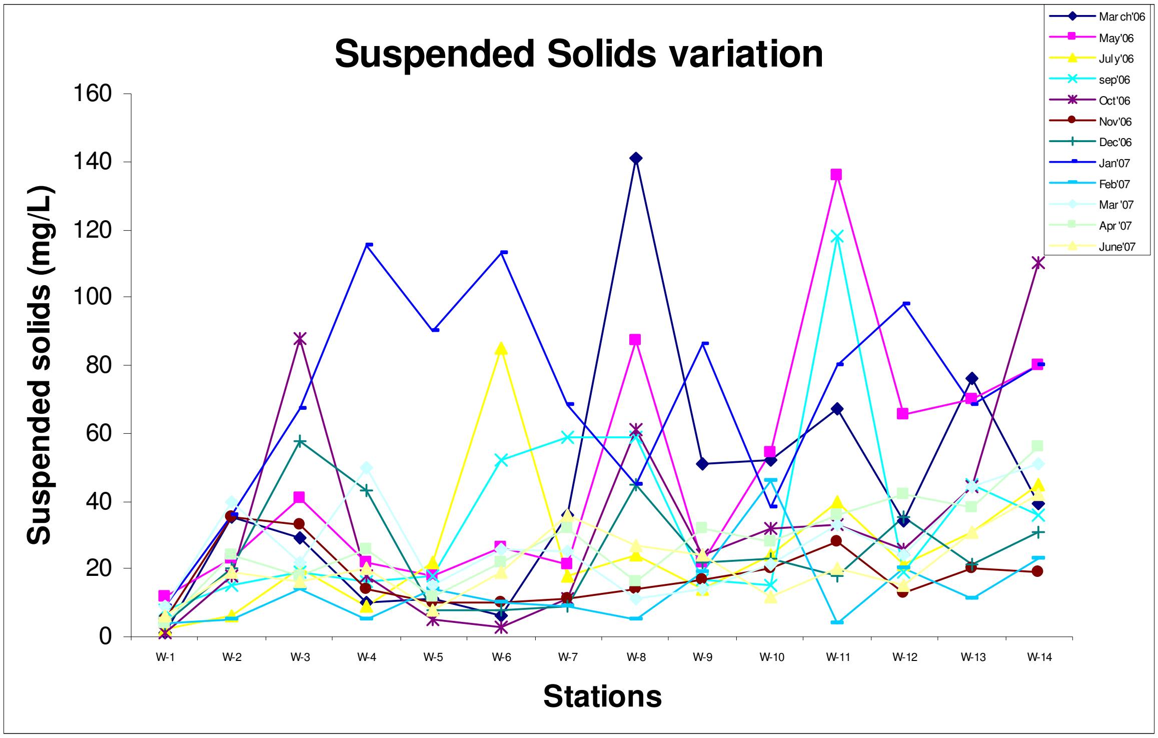

Figure 4.16 Trend in TSS at sampling points from March 2006-June 2007

Table 4-10; Total Suspended Solids in mg/l ; Laboratory Analysis data of Sungai Pencala at each site during March 2006- June 2007

Locations	March'06	May'06	July'06	Sep'06	Oct'06	Nov'06	Dec'06	Jan'07	Feb'07	Mar'07	Apr'07	June'07
W-1	1	12	2	8	1	5	4	9	4	9	4	6
W-2	35	23	6	15	18	35	20	36	5	40	24	19
W-3	29	41	20	19	88	33	58	67	14	22	18	16
W-4	10	22	9	16	18	14	43	115	5	50	26	20
W-5	11	18	22	18	5	10	8	90	14	15	12	8
W-6	6	27	85	52	3	10	8	113	10	26	22	19
W-7	36	22	18	59	11	11	9	68	9	25	32	36
W-8	141	87	24	59	61	14	45	45	5	11	16	27
W-9	51	22	14	17	24	17	22	86	19	14	32	24
W-10	52	55	24	15	32	20	23	38	46	21	28	12
W-11	67	136	40	118	33	28	18	80	4	33	36	20
W-12	34	66	21	19	26	13	35	98	20	24	42	15
W-13	76	70	31	45	44	20	21	68	11	44	38	31
W-14	39	80	45	36	110	19	31	80	23	51	56	42

4.1.11 Pesticides

Pesticides were not detected in the entire sampling period from March 2006- June 2007. Thus adverse effects to aquatic life from exposure to pesticides in the river are not likely to occur. Therefore the risk of adverse effects from pesticides appears to be minimal.

4.1.12 Heavy Metals

The Department of Environment reported higher concentrations of heavy metals on the west coast of Peninsular Malaysia than in other parts of the country because of extensive land use and industrialization (Department of Environment, 2002). Almost all the samples collected from the coastal waters of the country had values of lead, copper and cadmium exceeding the proposed standards of 0.05 mg/litres lead, 0.01 mg/litre copper and 0.005 mg/litre cadmium. The coastal waters of Perak and Penang recorded high levels of cadmium, copper, lead, mercury and nickel. In 1990, all the samples analyzed for nickel in Penang waters exceeded the proposed standard of 0.01 mg/litre, and in Perak, around 50 percent of the 41 samples collected had values exceeding the standard. However, analyses carried out by the Fisheries Research Institute indicated that the levels of heavy metals in Malaysian fish and shellfish samples did not pose a major threat to public health (DOE Malaysia, 2002)

Water pollution by toxic chemicals present in industrial waste effluents is a worldwide problem now. Both developed and developing countries are seriously affected due to this water pollution. Consequently, major water pollution in Malaysia is also caused by the discharge of industrial effluents. Many industries discharge wastes containing different inorganic compounds including heavy metals into natural freshwater bodies without prior treatment. However, the point sources of pollution in Malaysia come in the form of forest cleaning and earthworks, industrial effluents and wastes typically the agrobased industrial point sources (namely rubber and oil palm mills), domestic or animal farming sewage (Department of Environment, 2002). The Department of Environment (2002) also reported that industries such as tannery, chemical-based, electrical and electronic industries achieved average compliance of 81 %, 85 % and 86 % respectively. However, industries such as paper, textile, metal finishing and electroplating, food and beverages, and animal feed could not achieve more than 65 % compliance. In 2003, 129 premises or companies were taken to court and fined a total of RM 1 901 300.00 for offences under the Environmental Quality Act, 1974. Out of the total number of cases, 55 (43%) cases involved offences for polluting inland waters through discharges of effluent above the stipulated standard under section 25(1) of the Environmental Quality Act, 1974 (Department of Environment, 2003).

Oysters *Isognomon alatus* containing high concentrations of Zn, Cu, Pb and Cd were collected from the Sepang Besar River, and transferred to the Sepang Kecil River where the native oysters contain low metal concentrations. Oysters were exposed to 100 µg□g^{-1} of metals for two weeks followed by one week of depuration, (Katayon Saed *et al* 2004).

Heavy metals are usually found in water at concentration of around 1 – 100 ppb range. Most of the metals are naturally occurring. However, because of insolubility, high concentration of metals rarely occurs unless the pH is very low or an industrial source is releasing high concentrations. A decrease in pH would increase metal availability, lending itself to greater uptake by organisms and can cause physiological damage to aquatic life (Connell and Miller, 1984).

Water samples were collected in Sungai Pencala at 14 sampling stations. Cadmium, arsenic, lead and mercury were selected for analysis and continuously monitored at the same location for a period of one year. Inductively Coupled Plasma Emission Spectrometer (ICP-AES) Perkin Elmer 5300 Model was used for the entire analysis for this study. All the results were reported less than the detection limit. The very low concentrations of heavy metals pose significant difficulties to the use of Inductively Coupled Plasma Emission Spectrometer (ICP-AES). Hence some of the batch sample analyses were carried out using Inductively Coupled Plasma Mass Spectrometer (ICP-MS) model Perkin Elmer Elan 6000 as per USEPA 6020. The results are tabulated in Tale 4-11 to 4-15.

Metals that are naturally introduced into the river come primarily from such sources as rock weathering, soil erosion, or the dissolution of water-soluble salts. Naturally occurring metals move through aquatic environments independently of human activities, usually without any detrimental effects. (John et al 1995). Major sources of toxic metals arising from human activities are domestic and industrial wastewaters and their associated solid wastes. On the average, the USEPA estimates that 81 percent of the metals introduced into wastewater treatment plants comes from various regulated industries that dispose of their wastes into municipal sewer systems and that about 19 percent comes from consumer households in the form of common household products (U.S. Environmental Protection Agency, 1986).

4.1.12.1 Lead

Table 4-11 shows the lead concentrations at each sampling locations at Sungai Pencala. Lead concentrations ranged from 1 ppb to 7 ppb at Sungai Pencala. At Sampling location W-1 and W-2, there were no lead values detected. W-1 and W-2 sampling locations are in upstream and these sampling points are exposed fairly less amount of pollution sources. These are recreational areas where activities like jogging, fishing or camping are the kind of activities mostly takes place. Therefore, there were no significance levels of heavy metals detected. Similar trend of lead results have been maintained in all sampling results. At W-14, lead was detected as 7 ppb in July 2006, which is the extreme end of the Sungai Pencala gets mixed with Klang river. Fig 4.17 shows the pollution sources from the surrounding land use.

Figure 4.17 wastewater discharges into river at sampling location W-14,

The rest of the results show similar range between 1 ppb to 3.8 ppb. Sungai Pencala receives run off from surrounding residential, industrial and commercial area as it flows down stream. None of the observed lead concentrations except in W-14 in July 2006, in Sungai Pencala seem to be alarmingly high from a toxicological point of view. Nearly all of the observed lead concentrations were low and may be explained as a natural sources and processes.

Table 4-11 – Concentrations of Lead in Sungai Pencala at each sampling site

Sample ID	July 2006	November 2006	February 2007	April 2007	August 2007	September 2007
Unit	ppb	ppb	ppb	ppb	ppb	ppb
W1	<1	<1	<1	<1	<1	<1
W2	<1	<1	<1	<1	<1	<1
W3	2.6	1.1	2.3	1.6	2.1	2.2
W4	1.1	1.4	2.2	1.5	1.6	2.5
W5	1.7	1.3	1.8	2	1.5	2
W6	2.9	1.8	1.5	2.5	1.7	1.4
W7	1.7	2	1.6	2.2	1.3	1
W8	3	1	1.8	1.3	1.6	1
W9	2.6	1.8	2	1.5	2.1	<1
W10	2	2.6	1	1.7	2.4	<1
W11	2.6	2.4	1.9	2.3	2.6	<1
W12	2.8	2.9	1	2.1	2.8	<1
W13	1.9	2.1	1	1.8	2.5	2.6
W14	7	3.8	1.3	2.4	2.5	3.2

4.1.12.2 Mercury

From the Table 4-12, It can be noted that mercury was not detected at all sampling locations. Source of mercury pollution are not likely to occur in Sungai Pencala.

Table 4-12- Concentrations of mercury in Sungai Pencala at each sampling site

Sample ID	July 2006	November 2006	February 2007	April 2007	August 2007	September 2007
Unit	ppb	ppb	Ppb	ppb	Ppb	ppb
W1	<1	<1	<1	<1	<1	<1
W2	<1	<1	<1	<1	<1	<1
W3	<1	<1	<1	<1	<1	<1
W4	<1	<1	<1	<1	<1	<1
W5	<1	<1	<1	<1	<1	<1
W6	<1	<1	<1	<1	<1	<1
W7	<1	<1	<1	<1	<1	<1
W8	<1	<1	<1	<1	<1	<1
W9	<1	<1	<1	<1	<1	<1
W10	<1	<1	<1	<1	<1	<1
W11	<1	<1	<1	<1	<1	<1
W12	<1	<1	<1	<1	<1	<1
W13	<1	<1	<1	<1	<1	<1
W14	<1	<1	<1	<1	<1	<1

4.1.12.3 Chromium

Table 4-13 shows the chromium concentrations along Sungai Pencala, the concentrations ranging between 1 ppb to 4.1 ppb. There were no significant level of chromium detected in upstream W-1 and W-2 locations. July and November 2006 results shown similar trend for chromium as it flows down stream. The highest chromium concentration was detected as 4.1 ppb at W-14 in July 2006, which is the extreme end of the Sungai Pencala.

Table 3.14 - Concentrations of chromium in Sungai Pencala at each sampling site

Sample ID	July 2006	November 2006	February 2007	April 2007	August 2007	September 2007
Unit	ppb	ppb	Ppb	ppb	ppb	ppb
W1	<1	<1	<1	<1	<1	<1
W2	<1	<1	<1	<1	<1	<1
W3	1.1	1.7	<1	1	<1	<1
W4	1	<1	<1	<1	<1	<1
W5	1.2	<1	<1	<1	<1	<1
W6	1.2	<1	<1	<1	<1	<1
W7	<1	1.4	<1	1	<1	<1
W8	1.3	2.06	1	1	<1	<1
W9	2.8	1.6	1.2	<1	1.2	1.8
W10	1	2.12	1.5	1	<1	<1
W11	3.2	2.2	1	1	2.3	3.3
W12	3.5	1.5	1	1	1.4	2.2
W13	1.4	2.3	1.7	1	<1	<1
W14	4.1	1	1	2.8	<1	<1

4.1.12.4 Arsenic

Table 4-14 shows the Arsenic concentrations along Sungai Pencala, At W-1 and W-2 arsenic results were not detected as these locations are upstream and minimum exposures to pollution sources. Arsenic concentrations ranging between 2 ppb to 57.6 ppb, the highest arsenic level detected at W-9, this could be due to pollution sources from solid waste, domestic sewage, waste water discharge into the river stream. From W-3 to W-8, there were gradual increase in arsenic values and there was sudden increase in arsenic results at W-9 and the similar trend was observed in the entire study. At W-10 there was a reduction in arsenic results and again slightly increases at W-11 and the similar trend has been observed until W-14.

Table 4-14 – Concentrations of arsenic in Sungai Pencala at each sampling site

Sample ID	July 2006	November 2006	February 2007	April 2007	August 2007	September 2007
Unit	ppb	ppb	Ppb	ppb	ppb	ppb
W1	<1	<1	<1	<1	<1	<1
W2	<1	<1	<1	<1	<1	<1
W3	7.58	4.52	2.8	2	12.8	6.3
W4	5.6	5.68	3.1	2.5	3.2	4.8
W5	6.5	6.74	3	3.2	2.8	3.5
W6	6.59	5.23	2.1	1.8	4.9	5.1
W7	8.59	9.5	2.5	5.8	3.9	2.8
W8	13.3	19.6	4.6	6.4	22.8	12.7
W9	36.8	34.8	23	39.4	42.5	57.6
W10	8	9.3	2	3.5	12.6	9.6
W11	12.8	16.4	3.8	5.6	8.33	11
W12	10.6	14.8	12.5	12	18.1	21.3
W13	15.7	11.5	5	5.6	19.6	5.8
W14	22.4	5.7	4.9	18.2	25.2	12.8

4.1.12.5 Cadmium

From the Table 4-15, cadmium was not detected at any of the sampling locations. Cadmium pollution are not likely to occur in Sungai Pencala.

Table 4.15 – Concentrations of cadmium in Sungai Pencala at each sampling site

Sample ID	July 2006	November 2006	February 2007	April 2007	August 2007	September 2007
Unit	ppb	ppb	ppb	ppb	ppb	ppb
W1	<1	<1	<1	<1	<1	<1
W2	<1	<1	<1	<1	<1	<1
W3	<1	<1	<1	<1	<1	<1
W4	<1	<1	<1	<1	<1	<1
W5	<1	<1	<1	<1	<1	<1
W6	<1	<1	<1	<1	<1	<1
W7	<1	<1	<1	<1	<1	<1
W8	<1	<1	<1	<1	<1	<1
W9	<1	<1	<1	<1	<1	<1
W10	<1	<1	<1	<1	<1	<1
W11	<1	<1	<1	<1	<1	<1
W12	<1	<1	<1	<1	<1	<1
W13	<1	<1	<1	<1	<1	<1
W14	<1	<1	<1	<1	<1	<1

4.1.13 Microbiological Analysis

4.1.13.1 Total Bacterial Count and E Coli

Figures 4-18 and 4-19 show the E. coli and total bacterial count levels of the Sungai Pencala and its tributaries. Included in each figure are the E. coli and TBC level for each site. The E. coli and TBC levels measured on March 2006, to June 2007 were significantly higher in all sampling points except at upstream stations. In all the sampling locations except W-1 , E. coli levels in the Sungai Pencala was very much higher than the maximum level of Total Coliform contamination set by Interim National Water Quality Standard for Malaysia under Class II. This excessive level of E. coli contamination can be correlated with a heavy rainfall as the sampling was conducted after the heavy rain. Samples from surface runoff in sewered basins generally showed higher bacterial counts than runoff from non sewered basins (Katherine, 1999). The high levels of E. coli also appear in middle down stream of the Sungai Pencala as it flows through a relatively dense residential area. It is reasonable to expect that the high levels of E. coli are due primarily to discharge from residence sewer systems.

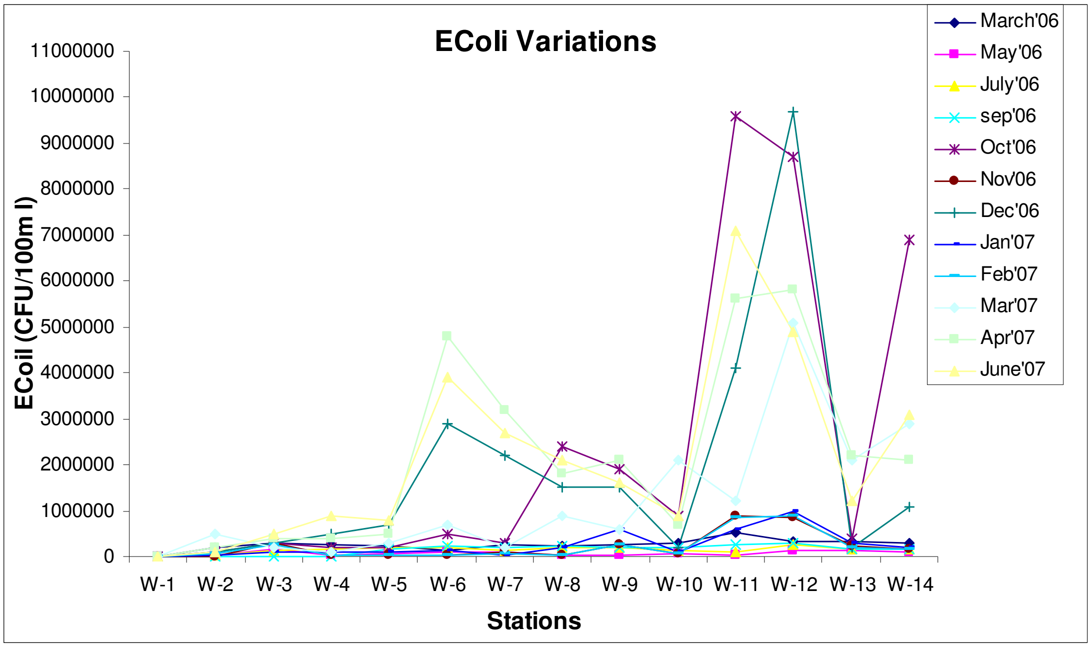

Figure 4-18 E Coli variation in Sungai Pencala , March 2006-June 2007

Table 4-16; E Coli in Sungai Pencala at each site during March 2006- June 2007

Loc	March'06	May'06	July'06	Sep'06	Oct'06	Nov'06	Dec'06	Jan'07	Feb'07	Mar'07	Apr'07	June'07
W-1	6	17	6	0	0	22	0	0	0	0	0	0
W-2	188000	19900	44000	700	100000	10000	90000	30000	70000	500000	200000	100000
W-3	294000	151000	145000	11000	300000	290000	300000	100000	270000	200000	400000	500000
W-4	267000	43000	157000	2000	200000	40000	500000	100000	30000	100000	400000	900000
W-5	223000	81000	211000	172000	200000	20000	700000	110000	20000	300000	500000	800000
W-6	141000	99000	201000	224000	500000	30000	2900000	130000	20000	700000	4800000	3900000
W-7	268000	83000	138000	198000	280000	90000	2200000	40000	70000	200000	3200000	2700000
W-8	244000	16700	193000	234000	2400000	40000	1500000	200000	30000	900000	1800000	2100000
W-9	277000	20700	198000	181000	1900000	270000	1500000	600000	260000	600000	2100000	1600000
W-10	311000	77000	123000	188000	900000	60000	200000	90000	50000	2100000	700000	900000
W-11	517000	16600	101000	251000	9600000	890000	4100000	600000	870000	1200000	5600000	7100000
W-12	327000	143000	256000	294000	8700000	870000	9700000	1000000	880000	5100000	5800000	4900000
W-13	331000	121000	166000	175000	390000	230000	200000	300000	210000	2100000	2200000	1200000
W-14	299000	102000	179000	163000	6900000	160000	1100000	200000	160000	2900000	2100000	3100000

Table 4-17; Total Bacterial Count in Sungai Pencala at each site during March 2006- June 2007

Locations	March'06	May'06	July'06	Sep'06	Oct'06	Nov'06	Dec'06	Jan'07	Feb'07	Mar'07	Apr'07	June'07
W-1	47	38	80	8	19	20	39	0	27	7	12	5
W-2	1140000	2670000	170000	59000	62000	30000	730000	150000	260000	77000	420000	930000
W-3	1810000	3140000	1220000	2010000	1580000	3670000	2170000	810000	510000	2940000	2180000	3570000
W-4	1770000	2910000	1260000	610000	188000	2110000	1030000	130000	1650000	160000	980000	1370000
W-5	1560000	1020000	1710000	2630000	510000	2660000	780000	100000	870000	70000	1010000	970000
W-6	870000	1920000	1540000	2180000	770000	310000	2540000	120000	640000	2680000	1810000	2050000
W-7	1720000	610000	1190000	3980000	980000	220000	1520000	60000	2010000	1010000	1220000	1850000
W-8	1570000	1530000	1470000	3970000	2010000	2410000	3470000	270000	1340000	1610000	1680000	3160000
W-9	1790000	2330000	1510000	2070000	1680000	2780000	2950000	290000	2590000	870000	2980000	3880000
W-10	2170000	5700000	1010000	3690000	1010000	3480000	810000	490000	2660000	3390000	1010000	1380000
W-11	4160000	10100000	880000	3910000	2710000	3570000	5100000	970000	470000	3050000	2860000	4150000
W-12	2340000	4400000	1820000	3840000	3800000	2350000	5800000	140000	3520000	2880000	3210000	4220000
W-13	2670000	3010000	1310000	3790000	940000	3970000	1690000	110000	3710000	3670000	1120000	1880000
W-14	1990000	3390000	1490000	2880000	1840000	3110000	4800000	70000	1470000	3510000	2860000	3990000

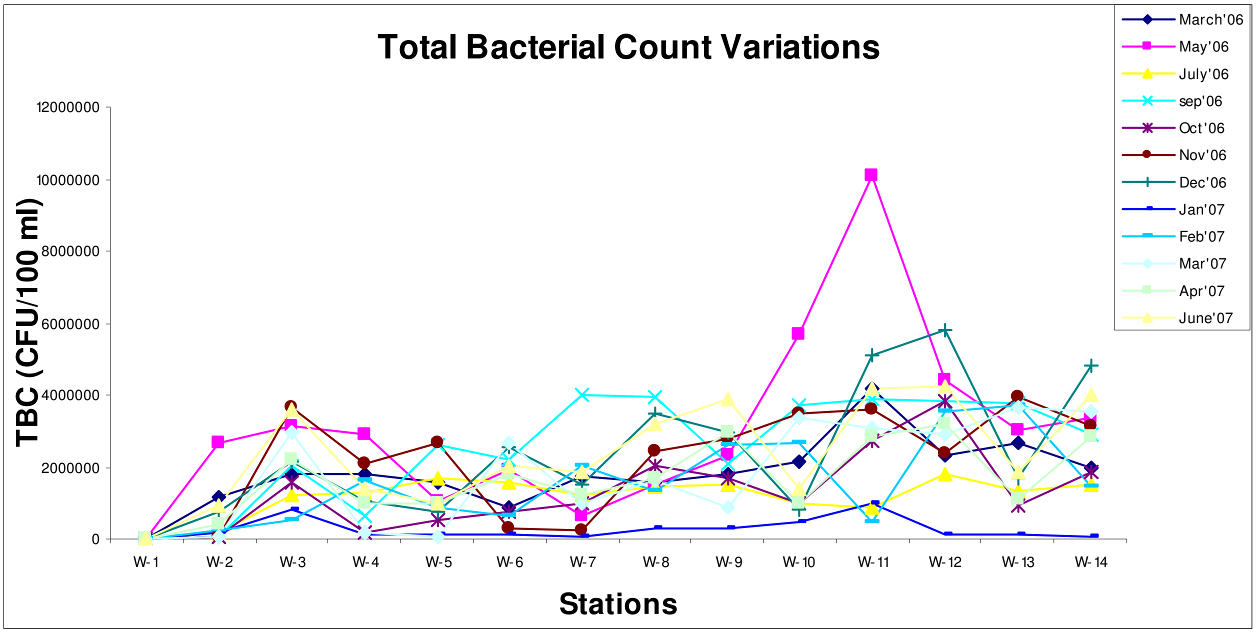

Figure 4-19 TBC variation at sampling location from March 2006-June 2007

4.1.14 Water Quality Index

The WQI is one of the most widely used of all existing water quality procedures. The overall results of six separate tests can be used to determine if a particular stretch of river is healthy. The water quality criteria formulated and adopted by DOE and provide the frame work for Interim National Water Quality Standards (INWQS). From INWQS, it is possible to identify the following classes which can service the respective beneficial uses. (DOE)

Class I	: Conservation of natural environment; protection of very sensitive aquatic species
Class II	: Water supply with conventional treatment; recreational use with body contact; protection of sensitive aquatic species.

Class III : Water supply with extensive treatment; water for livestock drinking of common and moderately tolerant species of aquatic life

Class IV : Water for irrigation

Class V : Water unsuitable for the above uses

Table 4-18; DOE Water Quality Index Classes

Parameters	Unit	Class I	Class II	Class III	Class IV	Class V
Ammoniacal Nitrogen	mg/l	< 0.1	0.1-0.3	0.3-0.9	0.9-2.7	>2.7
Biological Oxygen Demand	mg/l	<1	1-3	3-6	6-12	>12
Chemical Oxygen Demand	mg/l	<10	10-25	25-50	50-100	>100
Dissolved Oxygen	mg/l	>7	5-7	3-5	1-3	<1
pH	-	>7	6.0-7.0	5.0-6.0	<5	>5
Total Suspended Solids	mg/l	<25	25-50	50-150	150-300	>300
Water Quality Index	-	>92.7	76.5-92.7	51.9-76.5	31-51.9	<31

Source: DOE (Department of Environment)

Formula for calculating Water Quality Index (WQI)

WOI = 0.22*SIDO + 0.19*SIBOD + 0.16*SICOD +
0.15*SIAN + 0.16*SISS + 0.12*SIpH

where SI refers to the Sub index function for each of the given parameters.

Water quality Index

Table 4-19 ; Water Quality Index along Sungai Pencala

Locations	March'06	May'06	July'06	Sep'06	Oct'06	Nov'06	Dec'06	Jan'07	Feb'07	Mar'07	Apr'07	June'07	**Ave**	**CLASS**
W-1	97	93	93	95	96	95	93	97	97	94	95	93	**95**	**I**
W-2	74	65	58	80	80	80	78	84	83	76	83	81	**77**	**II**
W-3	24	27	71	52	37	46	28	51	40	60	43	38	**43**	**IV**
W-4	65	46	69	72	68	80	50	75	70	71	63	69	**66**	**III**
W-5	71	60	40	65	59	81	66	74	69	67	64	69	**66**	**III**
W-6	69	52	28	55	60	74	63	74	65	60	50	57	**59**	**III**
W-7	28	40	44	42	54	72	62	64	56	61	51	50	**52**	**III**
W-8	18	34	37	32	36	67	37	63	60	51	57	47	**45**	**IV**
W-9	16	24	36	45	39	57	35	53	51	51	46	44	**42**	**IV**
W-10	18	27	40	57	34	54	36	63	51	44	46	47	**43**	**IV**
W-11	16	8	24	20	23	34	33	51	48	25	27	33	**29**	**IV**
W-12	22	24	28	29	31	44	26	45	38	39	33	34	**33**	**IV**
W-13	19	20	32	43	46	53	43	56	60	47	33	44	**41**	**IV**
W-14	22	18	27	33	23	47	37	52	53	37	29	48	**35**	**IV**

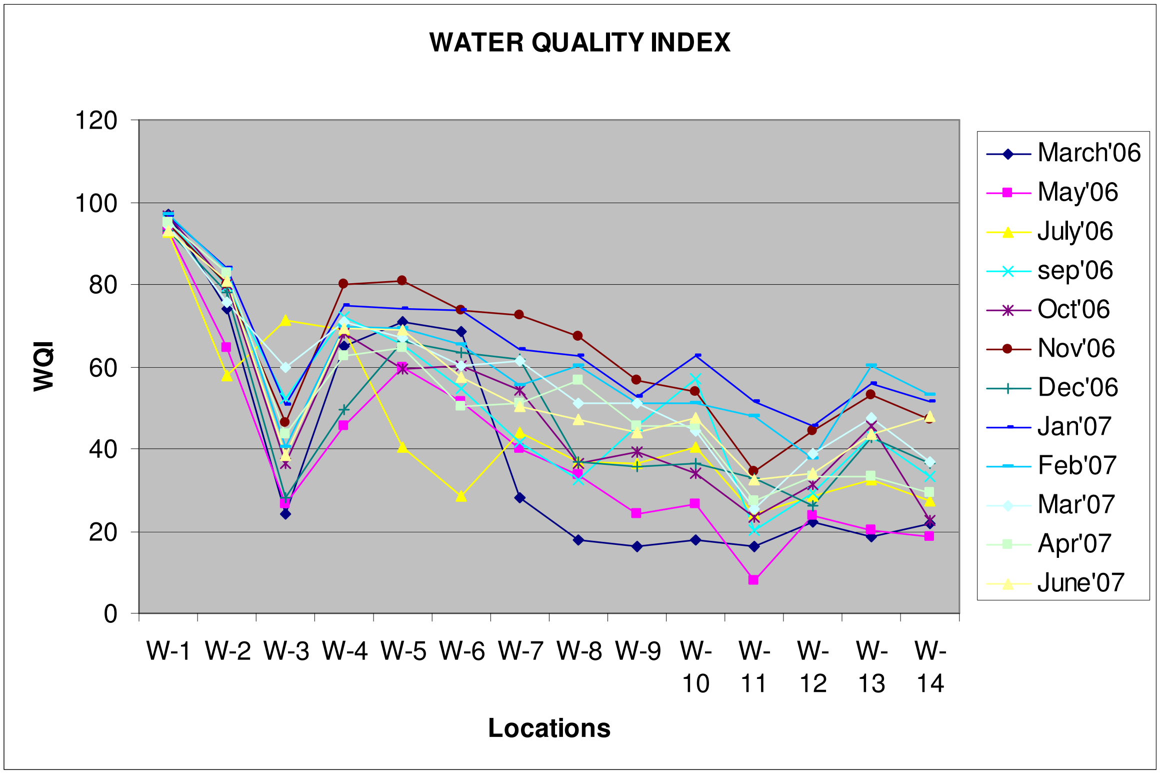

Fig 4-20 Water quality Index along Sungai Pencala

In order to view the recent trend of the pollution in Sungai Pencala, analysis of the Water Quality Index of 14 Monitoring stations were carried out and tabulated in Table 3-20. Figure 4-20 illustrates that in general the water quality is good at upstream near Stream upon Bukit Kiara, W-1 which is the source point of the river as the average WQI is about 95. The index then slightly fluctuated at about 77 as the river flows through KLGCC before Rimba Kiara at W-2. At W-3 the WQI dropped rapidly to 43 due to heavy pollution sources from wet market activities and construction works. Then the WQI improved slightly at W-4 and W-5, where treated sewage water from Indah Water gets mixed up with the stream. At W-6 WQI again dropped slightly and the trend remains until location W-10. Then the WQI again dropped at W-11 to 29 where there are sources of industrial pollution was observed from the industrial area. At W-12 where there are various sources of kitchen waste, organic wastes, sewage and solid waste from surrounding residence, the WQI reported was 33. At

W-13 WQI improved very slightly to 41 and again decreased to 35. The upstream of the river at W-1 falls under Class I of the DOE standards. As the river flows through the middle stream at W-4, W-5, W-6, W-7 the streams are classified under Class III. At W-3 and from W-8- W-14 the stream is classified under Class IV of the DOE standards. This shows the deterioration of the Sungai Pencala as it flows through the high density populated urbanized area. The quality of the river steadily deteriorates as it meanders further downstream, and worse, it begins to look like an open sewer.

4.2 Bioaccumulations of heavy metals in aquatic life at Sungai Penchala

4.2.1 Results and Discussion

Depending on the conditions of their habitats, plants may accumulate heavy metals in quantities considerably exceeding their content in the habitat (Miryakova, 1996). Furthermore, the environmental effects resulting from the bioaccumulation and evidence that a persistent material may be present in an effluent necessitates assessment of its rate and degree of uptake by aquatic organisms exposed to low levels of the chemical, with analysis of organs and tissues (Wollast, 1982).

Fish samples were collected in the three locations and plant samples were collected at five locations. The fish and plant samples were analysed in duplicate and the results are tabulated in Tables 4-20 to 4-23. The summaries of quality control data and certified reference material results are enclosed in Appendix D

Table 4-20 , Heavy metals analysis in fish in August 2007

Location	W-1 (A)	W-1 (B)	W-2 (A)	W-2(B)	W-12 (A)	W-12 (B)
Unit	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
As	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**0.089**	**0.082**
Cd	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**0.085**	**0.114**
Cr	**<0.05**	**<0.05**	**0.142**	**0.191**	**0.262**	**0.325**
Pb	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**0.089**	**0.110**
Hg	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**<0.05**

Table 4-21, Heavy metals analysis in fish samples in September 2007

Location	W-1 (A)	W-1 (B)	W-2 (A)	W-2 (B)	W-12 (A)	W-12 (B)
Unit	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
As	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**0.045**	**0.082**
Cd	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**0.100**	**0.093**
Cr	**<0.05**	**<0.05**	**0.058**	**0.064**	**0.337**	**0.351**
Pb	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**0.071**	**0.067**
Hg	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**<0.05**

Table 4-22, Heavy metals analysis in plant samples in August 2007

Location	**W-1 (A)**	**W-1 (B)**	**W-2 (A)**	**W-2 (B)**	**W- 9 (A)**	**W-9 (B)**	**W-11 (A)**	**W-11 (B)**	**W- 12 (A)**
Unit	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**
As	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**0.44**	**0.59**	**0.19**	**0.16**	**0.58**
Cd	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**0.15**	**<0.05**	**<0.05**	**<0.05**	**<0.05**
Cr	**<0.05**	**<0.05**	**0.06**	**0.07**	**0.25**	**0.26**	**0.17**	**0.14**	**0.49**
Pb	**<0.05**	**<0.05**	**0.07**	**0.08**	**0.38**	**0.36**	**0.27**	**0.23**	**0.21**
Hg	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**<0.05**

Table 4-23, Heavy metals analysis in plant samples in September 2007

Location	W-1 (A)	W-1 (B)	W-2 (A)	W-2(B)	W- 9 (A)	W-9 (B)	W-11 (A)	W-11 (B)	W-12(A)
Unit	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
As	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**0.42**	**0.39**	**0.22**	**0.16**	**0.75**
Cd	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**0.09**	**<0.05**	**<0.05**	**<0.05**	**<0.05**
Cr	**<0.05**	**<0.05**	**<0.05**	**0.10**	**0.22**	**0.20**	**0.25**	**0.08**	**0.43**
Pb	**<0.05**	**<0.05**	**0.06**	**0.05**	**0.28**	**0.34**	**0.70**	**0.57**	**0.17**
Hg	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**<0.05**

4.2.2 Heavy metals analysis in fish and plant samples

In Malaysia, the presence of arsenopyrite and other arsenical ores in association with tin, iron, gold, lead, copper and zinc ores have been reported in various mines both in the Peninsula as well as in Sabah and Sarawak (Department of Environment, 1986a). Major anthropogenic sources which release arsenic into the air, water and soil are ore smelters, cement manufacturing, combustion of fossil fuels and extensive use of arsenical pesticides. Some monitoring data obtained through Global Environmental Monitoring System (GEMS) under the coordination of WHO shows the total arsenic concentration for Sg. Skudai is 0.005 mg/L (Department of Environment, 1986a). Besides that, from the studies in the Sg. Langat basin, levels of arsenic have been reported to range between 0.003 to 0.049 mg/L (Department of Environment, 1998). Accumulation of arsenic in herbs in Poland was found to be 1.05 mg/kg (Lozak *et al*., 2001).

Fish and plant samples were collected from five sampling points along Sg. Pencala in August 2007 and September 2007 for this study. The samples were analyzed for heavy metals namely arsenic, cadmium, chromium and lead using Inductively Coupled Plasma Mass Spectrometer (ICP MS) while mercury was analyzed by Flow Injection Mercury analyzer (FIMS). The samples were analyzed in wet condition and the results were reported on wet weight basis. Samples were analyzed in duplicates.

4.2.2.1 Heavy metals analysis in fish samples in August

The average results for fish samples collected in August 2007 are summarized in Table 4-24 and Figure 4-21.

Table 4-24: Average Results of Fish Sample for August 2007

Locations	**As mg/kg**	**Cd mg/kg**	**Cr mg/kg**	**Pb mg/kg**	**Hg mg/kg**
W1	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**<0.05**
W2	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**<0.05**
W12	**0.086**	**0.099**	**0.294**	**0.099**	**<0.05**

Table 4.24 and Figure 4.21 shows that there were no heavy metals detected in fish samples at sampling location W- 1 and sampling point W-2 in August. W-1 and W-2 sampling locations are in upstream and these sampling points are exposed fairly less amount of pollution sources. These are recreational areas where activities like jogging, fishing or camping are the kind of activities mostly takes place. Therefore, there were no significance levels of heavy metals detected. The heavy metal content is expected to increase as the river flow to into the high density populated urbanized TTDI Township where the stream is deepened, widened and turn into a concrete channelized river. The river quality started to get deteriorated due to pollution from various sources such as domestic sewage, industrial discharge and different types of solid waste.

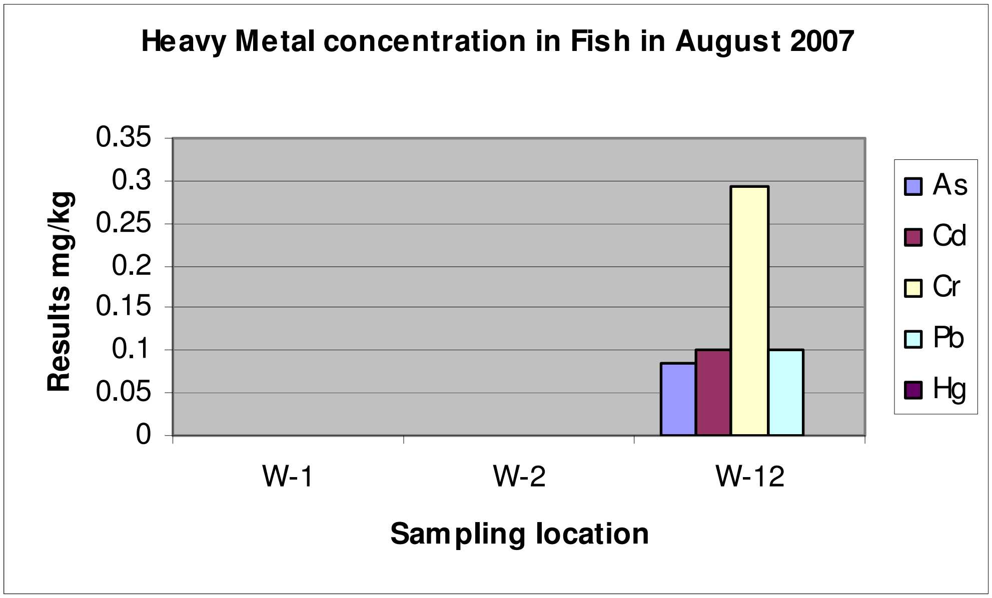

Figure 4.21: Heavy metals concentration in fish sample in August 2007

At W12, the content of arsenic, cadmium, chromium and lead in fish samples were 0.086, 0.099, 0.294 and 0.099 mg/kg respectively. Cadmium and lead were found to be very high. Mercury was not detected in the fish samples. W-12 sampling location a tributary from Sg Way was found to be heavily polluted with all kind of solid wastes from sewages, house hold things like metallic waste, plastic waste, kitchen wastes, and untreated sewage from Indah water. Figure 4-22 shows the extent of solid waste pollution at this sampling location. It was noted that W-12 was just next to the busy stretch of Federal highway and nearby W-12 there were activities such as wet market, commercial activities such as hardware shops, sundry shops and food stalls. Besides, this sampling point was surrounded by some low cost housing areas just 100 meters away. The Free Trade Zone, of Sg Way, Petaling Jaya was found to be very near to this sampling point as well. The electronic company Western Digital Company was at the corner of the road and was only about 500 meters away from the sampling point.

Fig 4-22 Pollution sources in the sampling location W-12

4.2.2.2 Heavy metals analysis in plant samples in August

Table 4-25 and Figure 4.23 shows the results of heavy metals in plant samples. There were no heavy metals detected in plant samples at sampling location W- 1 and sampling point

W-2 in August. W-1 and W-2 sampling locations are in upstream and these sampling points are exposed fairly less amount of pollution sources as mentioned earlier.

Table 4-25: Average Results of Plant Samples for August 2007

Locations	**As mg/kg**	**Cd mg/kg**	**Cr mg/kg**	**Pb mg/kg**	**Hg mg/kg**
W1	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**<0.05**
W2	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**<0.05**
W9	**0.515**	**<0.05**	**0.255**	**0.370**	**<0.05**
W11	**0.175**	**<0.05**	**0.155**	**0.250**	**<0.05**
W12	**0.58**	**<0.05**	**0.490**	**0.210**	**<0.05**

At sampling location W-9 which is surrounded by residential and commercial area, arsenic was detected as 0.515 in plant samples. Lead was detected in the range of 0.37 mg/kg in plant samples while chromium was detected as 0.255 mg/kg. These results may indicate the long term bioaccumulations in the plant samples due to pollution sources at this sampling location.

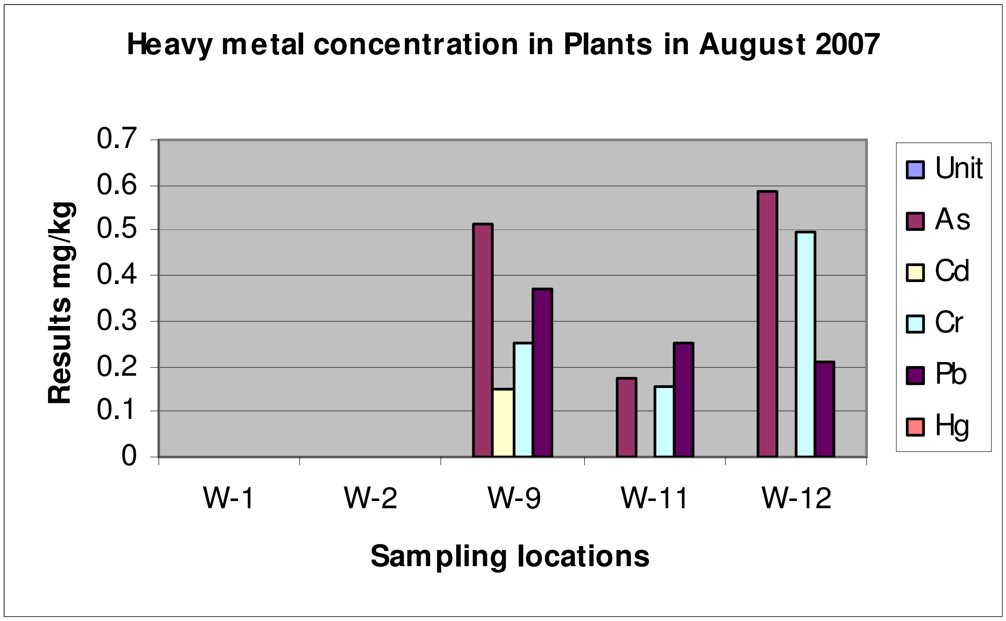

Figure 4-23: Heavy metals concentration in plant samples in August 2007

This could be due to pollution sources from solid waste, untreated domestic sewage, waste water discharge from the commercial areas nearby into the river stream and this location is also near a busy road.

Arsenic content in plant samples was found to be the highest. At sampling location W-11, arsenic was present in the range of 0.175 mg/kg in plant samples while in water sample arsenic was detected at 8.33 ppb. Cadmium was not detected in August, chromium was detected at 0.155 mg/kg and lead was detected at 0.25 mg/kg at the significance level. This sampling location W-11, tributary from Jalan Templer/Tandang is fully surrounded by many industries which had caused the high level of heavy metal content.

Fig 4-24 shows the discharge from the metal industry into the river at sampling location W-11.

Fig 4.24 clearly shows the discharge from the nearby galvanizing metal industry contributed to this significant level of heavy metal concentrations at this location.

At sampling location W12, arsenic content in plant samples was reported to be 0.58 mg/kg (Table 4-25). Cadmium and Mercury were below detection limits in plant samples. Chromium was detected at 0.490 mg/kg while lead was to be reported in the range 0.210 mg/kg from Table 4-25. W-12 sampling location was heavily polluted with all kind of solid wastes from sewages, household products, plastic waste, kitchen wastes, and untreated sewage from Indah Water and hence contributes heavy pollution to the river as discussed in section 4.2.2.1. The pollution level at location W-12 can be seen in Figure 4-22.

4.2.2.3 Heavy metals analysis in fish samples in September 2007

The average results for fish samples collected in Sept 2007 are summarized in Table 4.26

Table 4.26: Average Results of Fish Samples for September 2007

Locations	**As mg/kg**	**Cd mg/kg**	**Cr mg/kg**	**Pb mg/kg**	**Hg mg/kg**
W1	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**<0.05**
W2	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**<0.05**
W12	**0.064**	**0.097**	**0.344**	**0.069**	**<0.05**

Table 4-26, shows that there were no heavy metals detected in fish samples at sampling location W-1 and sampling point W-2 in September 2007. W-1 and W-2 sampling locations are in upstream and also this is a recreational area where activities like fishing or camping taking place, Therefore, there were is significance level of heavy metals detected. The heavy metal contents are expected to increase as the river flow to into the high density populated urbanized TTDI Township. The river quality started getting deteriorated due to various pollution sources such as domestic sewage, industrial discharge and solid waste.

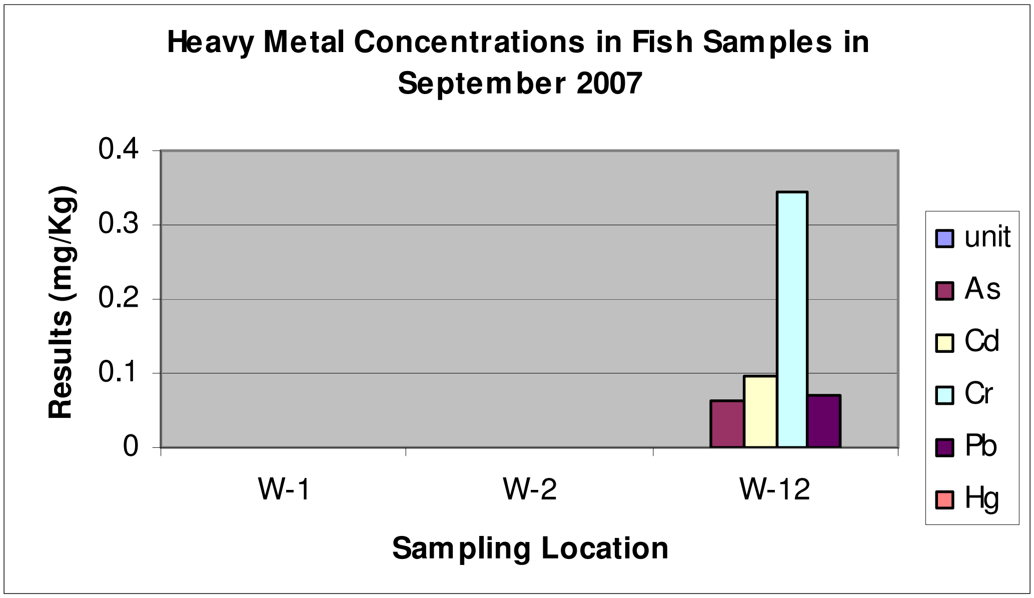

Figure 4.25: Heavy metals concentrations in fish samples in September 2007

At sampling location W-12, As, Cd, Cr, and Pb were detected except mercury. Chromium was detected slightly significant level at 0.344 mg/kg. Arsenic at 0.064 mg/kg, cadmium 0.097 mg/kg and lead detected at 0.069 mg/kg slightly above than the detection limit. However the heavy metal content in fish samples was slightly lower than the month of August except for chromium which was slightly higher. The lower level in the heavy metal content in fish samples could be due to the weather condition whereby raining season tend to dilute the heavy metal level in water samples.

Figure 4.25 shows the fish sample results in September 2007. At sampling location W-12 as discussed in the section 4.2.2.1, there were many sources of pollution at this sampling location. This sampling point was fully dumped with all kinds of wastes including metallic, plastic, organic, sewage wastes and the leachates from solid waste could cause the results to be detected at significant level.

4.2.2.4 Heavy metals analysis in plant samples in September 2007

Similar to the month of August, September sampling results also shows that sampling point W-1 and W-2 do not have significance levels of heavy metals as these two sampling locations are at upstream.

Table 4.27: Average Results of Plant Samples for September 2007

Locations	**As mg/kg**	**Cd mg/kg**	**Cr mg/kg**	**Pb mg/kg**	**Hg mg/kg**
W1	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**<0.05**
W2	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**<0.05**
W9	**0.405**	**<0.05**	**0.210**	**0.310**	**<0.05**
W11	**0.190**	**<0.05**	**0.165**	**0.635**	**<0.05**
W12	**0.750**	**<0.05**	**0.430**	**0.170**	**<0.05**

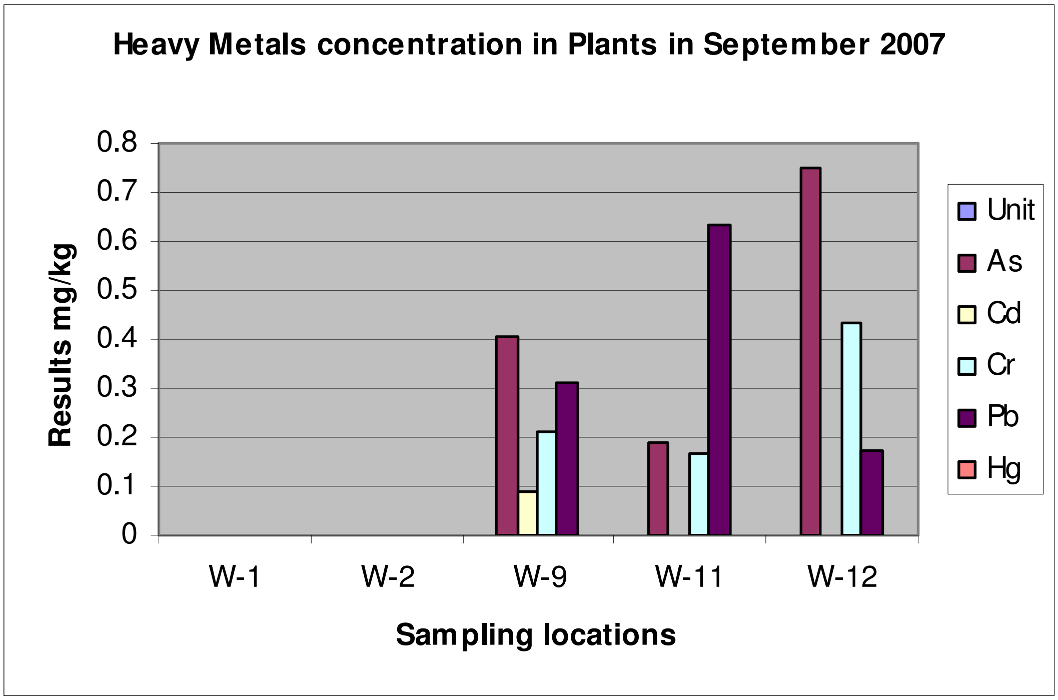

Figure 4-26: Concentration of heavy metals in plants in September 2007

At sampling location W-9, lead was detected as 0.31 mg/kg in plant samples and the same trend of results were obtained for the plant samples in August. This could be due to pollution sources from solid waste, domestic sewage, wastewater discharge into the river stream. An arsenic result at W-9 was 0.405 mg/kg may indicate the long term bioaccumulations in the plant samples due to pollution sources. Chromium was reported as 0.21 mg/kg cadmium and mercury were below detection limits in sampling locations as same W-9 as in August sampling.

At sampling location W-11 only plant samples were collected and analyzed. Cadmium and mercury results were detected below detection limits. Arsenic was reported at 0.190 mg/kg in plant samples. Chromium was reported at 0.165 mg/kg in plant samples. Lead was reported at 0.635mg/kg in plant at significant level. This could be due to industrial discharge let in to the river from nearby industries at sampling location W-11. This sampling location is fully surrounded by industrial area. At sampling location W-12, arsenic was reported at 0.75 mg/kg. It is observed that plants sample results for arsenic are higher compared to fish sample results. Cadmium and mercury were below detection limits in plants samples. Chromium was detected as 0.43 mg/kg in plant samples and lead was reported as 0.17 mg/kg. This sampling location as mentioned earlier is a area which is heavily polluted with domestic sewage, kitchen wastes, metallic and organic wastes.

4.2.2.5 Possible Bioaccumulations of heavy metals in fish and plant samples

Water samples were analyzed for heavy metals to compute the bioaccumulations factor of the heavy metal studied. Bioconcentration Factor (BF) refers to a constant proportionality between the concentration of a chemical in the organisms and in its external medium, (Sadiq, 1992). The Bioaccumulations factor (BF) was calculated as below:

$$\text{BF} = \frac{\text{Concentration in organism}}{\text{Concentration in the medium}}$$

Table 4-28, shows the water samples analysis results from ICP MS. At sampling locations of W-1 and W-2 there are is significant level of heavy metals detected and hence there is no significant heavy metal was reported for fish and plant samples. Table 4-29 and 4-30 shows the summary bioaccumulation factor in fish and plant samples.

Table 4-28: Heavy metals level in water samples in August and Sept 2007

Location		As (ppb)	Cd (ppb)	Cr (ppb)	Pb (ppb)	Hg (ppb)
W-1	Aug	<1.0	<1.0	<1.0	<1.0	<1.0
	Sept	<1.0	<1.0	<1.0	<1.0	<1.0
W-2	Aug	<1.0	<1.0	<1.0	<1.0	<1.0
	Sept	<1.0	<1.0	<1.0	<1.0	<1.0
W-9	Aug	42.5	<1.0	1.2	2.1	<1.0
	Sep	57.6	<1.0	1.8	<1.0	<1.0
W-11	Aug	8.33	<1.0	2.3	2.6	<1
	Sep	11	<1.0	3.3	<1.0	<1.0
W-12	Aug	18.1	<1.0	2	2.8	<1.0
	Sep	21.3	<1.0	2.2	<1.0	<1.0

Table 4-29; BF of heavy metals for fish samples in Sungai Pencala

	Location	As	Cd	Cr	Pb	Hg
W1	Aug	-	-	-	-	-
	Sept	-	-	-	-	-
W2	Aug	-	-	-	-	-
	Sept	-	-	-	-	-
W12	Aug	4.77	-	147	49.5	-
	Sept	2.76	-	172	-	-

Table 4-30 : BF of heavy metals for plant samples in Sungai Pencala

	Location	As	Cd	Cr	Pb	Hg
W1	Aug	-	-	-	-	-
	Sept	-	-	-	-	-
W2	Aug	-	-	-	-	-
	Sept	-	-	-	-	-
W9	Aug	12	-	250	185	-
	Sept	7.1	-	105	-	-
W11	Aug	21	-	80	83	-
	Sept	17	-	55	-	-
W12	Aug	32	-	245	70	-
	Sept	35	-	215	-	-

4.2.2.6 Arsenic bioaccumulations

At sampling location W-9, arsenic level in water sample was 42.5 ppb while in plant samples was as 0.51 mg/kg. Arsenic shows the bioaccumulations mechanism by a factor of approximately 12 times as this location is mainly surrounded by commercial area and this is a main road where heavy pollution sources from the vehicles and automotives is observed. At Sampling location W-11 arsenic was detected as 8.33 ppb in water and was 0.175 mg/kg in plant sample with Bioaccumulations ratio of approximately 21 times and this location is fully surrounded by many industries. Arsenic levels contributed to the river could be from the industrial operation.

At sampling location W-12, which is a tributary from Sg Way, 18.1 ppb of arsenic was reported in water samples and in fish and plants were detected as 0.086 mg/kg and 0.58 mg/kg respectively. Household wastes from the surrounding residential area cause the arsenic values to be high. The bioaccumulations factor for fish samples is approximately 5 and for the plant samples approximately 30 times.

In September at W-9, arsenic results in water sample was reported to be 57.6 ppb and in plant samples arsenic was found to be 0.405 mg/kg which shows the bioaccumulation process in the plant samples has occurred by the bioaccumulations factor of 7 times from the water samples to plant samples. Arsenic concentrations at sampling location W-11 was shown to be 11 ppb correspondingly in plant samples it was 0.19 mg/kg by magnifying factor of 17. At sampling location W-12 , the concentration of arsenic was shown as 21.3 ppb , plant and fish samples results were 0.75 mg/kg and 0.064 respectively. In plant sample the Bioaccumulations factor was 37 and in fish sample was only 3. There are no systematic correlation in arsenic bioaccumulation was observed between the sampling points and the samples because of the type plants and fish species.

Bioconcentration factors (BF) in freshwater invertebrates and fish for arsenic compounds are lower than for marine organisms (EHC 224, 2001). In general, bottom feeders accumulate more As in their soft tissues than the fishes. Bioaccumulations of As is influenced by the route of uptake by aquatic organisms. Direct uptake which is absorption by gill tissues is more dependent on concentrations in the external media than indirect uptake. As accumulation is influenced by its concentrations in the water itself, especially in organism that utilize gill tissue as the main route for nutrient uptake (Humtsoe *et al.,* 2007).

4.2.2.7 Lead Bioaccumulations

Lead was reported as 2.1 ppb in water samples at sampling location W-9, the level in the plant was 0.37 mg/kg at a significant level with the bioaccumulations factor of 185 times. At W-11, the lead value in water sample was reported as 2.6 ppb and in plant samples lead reported as 0.25 mg/kg with 125 times bioaccumulation. At W-12 the lead value in water sample was reported as 2.8 ppb similar to W-11 and the fish and plant samples were detected as 0.099 mg/kg with 30 times of bioaccumulation factor and 0.21mg/kg with a bioaccumulation factor of 70 times respectively. Figures 4.6 and 4.7 show the comparison between water sample results and both fish and plant results that shows the bioaccumulations process had taken place at W9, W11 and W12 sampling locations.

In September at sampling location W-1 and W-2, there were no significant levels of heavy metals were detected. At sampling location W-9, lead concentration at all locations, W-9, W-11 and W-12 were not detected in water samples due to heavy rain before sampling. But the plants samples were detected for lead at W-9 as 0.31 mg/kg, W-11 as 0.635 mg/kg and W-12 as 0.17 mg/kg. The lead results show significantly higher results in plant at all sampling locations.

4.2.2.8 Cadmium Bioaccumulation

From the Table 4-28, cadmium was not reported at any of the sampling points. Plant samples taken from W-9, W-11 and W-12 cadmium results were reported less than the reporting limit. But in fish sample taken from the sampling location W-12 shows the cadmium value as 0.099 mg/kg at very low level. Although cadmium was below detection limit in water samples, fish sample showed cadmium as 0.09 mg/kg, which indicates that the bioaccumulation process occurred at this sampling location. Cadmium was also not reported in any of the sampling points in September 2007 (Table 4.6). In plant samples taken from W-9, W-11 and W-12 cadmium results were reported less than the reporting limit. But in fish samples at W-12 shows the cadmium detected at 0.097 mg/kg very low level. Although cadmium was below detection limit in water samples, fish sample showed cadmium at 0.097 mg/kg, which indicates the bioaccumulations process, occurred in this sampling location.

4.2.2.9 Chromium Bioaccumulations

Chromium was detected as 1.2 ppb in water samples slightly higher than the detection limit at sampling location W-9 and it was reported as 0.255 mg/kg in the plants by a factor of approximately 200 times and confirms the Bioaccumulations at this sampling location in the month of August. The concentration of chromium could be due to the industrial discharge from the surrounding industries and residential area. At sampling location W-11 the chromium value in water sample was 2.3 ppb whereas in plant samples was 0.155 mg/kg with a bioaccumulation factor of approximately 70 times. At sampling location W-12 in water sample chromium was reported as 2.0 ppb whereas in plant and fish samples were reported as 0.490 mg/kg and 0.294 mg/kg respectively with the factor of 250 and 150 respectively. Bioaccumulation ratio shows high in plants sample compared to fish samples.

In September, chromium was detected as 1.8 ppb slightly higher than the detection limit at sampling location W-9. Chromium was reported in plant samples as 0.210 mg/kg while in water samples as 1.82 ppb which is about 100 times bioaccumulations. These results clearly indicates that there are bioaccumulation of heavy metals in aquatic organisms. At sampling location W-11 only plant samples were analysed. Chromium was reported as 0.165 mg/kg in plant samples and in water samples as 3.3 ppb which is by a bioaccumulation factor of 50. At sampling location W-12, fish and plant samples were collected in September, Chromium was detected at 0.43 mg/kg in plant samples and in fish samples it was reported at 0.344 mg/kg whereas in water samples chromium was detected at 2.2 ppb level.

4.2.2.10 Mercury Bioaccumulation

Mercury was not detected in any of the sampling points in water samples and also in both plant and fish samples. Mercury bioaccumulation along the foodwebs, principally based on cumulative transfers of the methylated form of the metal (monomethylmercury, MMHg), can lead to extremely high concentrations in piscivorous species at the top of the trophic networks (Boudou and Ribeyre, 1996; Morel *et al.,* 1998; Wiener *et al.,* 2003) and to considerable mercury burdens in the whole fish biomass. For example, mass balance determination for total Hg and MMHg in the Little Rock Lake (Wisconsin, USA) shows that among the different biotic pools (seston, zooplankton, fish), the amount of mercury accumulated in fish is equivalent to about 65% of the total mercury estimated in the water column; for MMHg, the amount in fish is 4.7 times greater than in the whole water compartment (Watras *et al.,* 1994).

4.2.3 Comparison of Bioaccumulation of heavy metal in fish and plant samples

Figures 4-27 & 4-28 show the comparison of heavy metal content in water, fish, and plants to be correlated with the Bioaccumulations process in the aquatic organisms in the river system in August and September sampling months. The systematic comparison is difficult for heavy metals bioaccumulations of the Sungai Pencala, not only because of habitat diversity, but also because of incomplete information collected. From the column graph, it can be seen that at sampling location W- 12 in both August and September months have the highest heavy metals constituents in plant samples. Most of the heavy metals been detected except for mercury. However there is no systematic correlation was observed for bioaccumulations factor on different heavy metals. It depends of the habitat and aquatic species of the river.

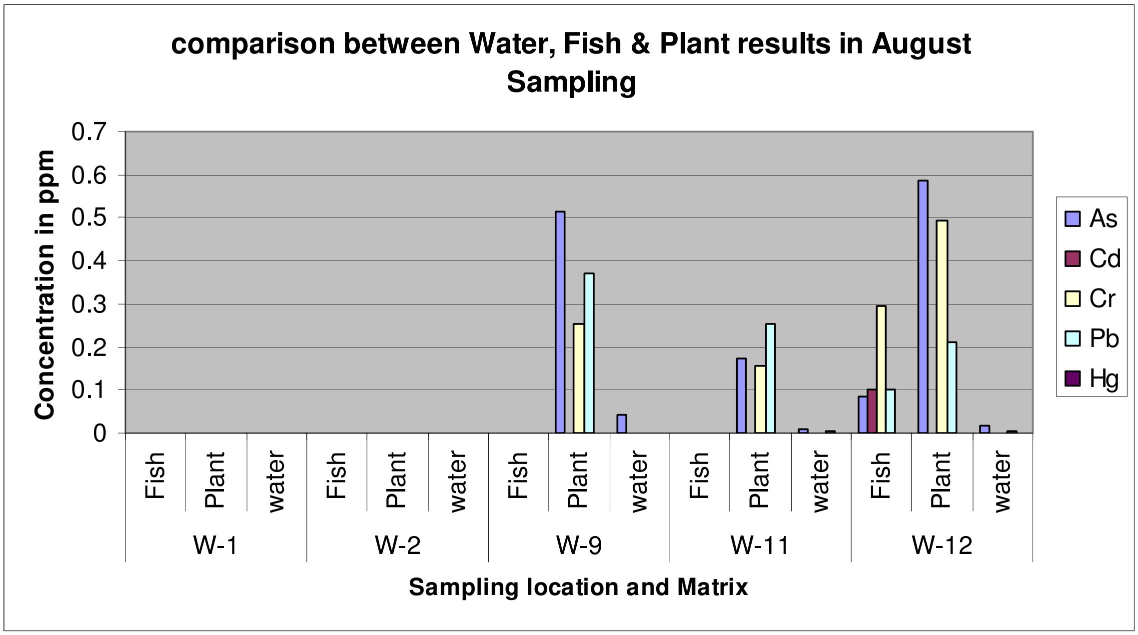

Figure 4-27, The comparison of concentration of metals in different types of samples in August 2007 sampling period

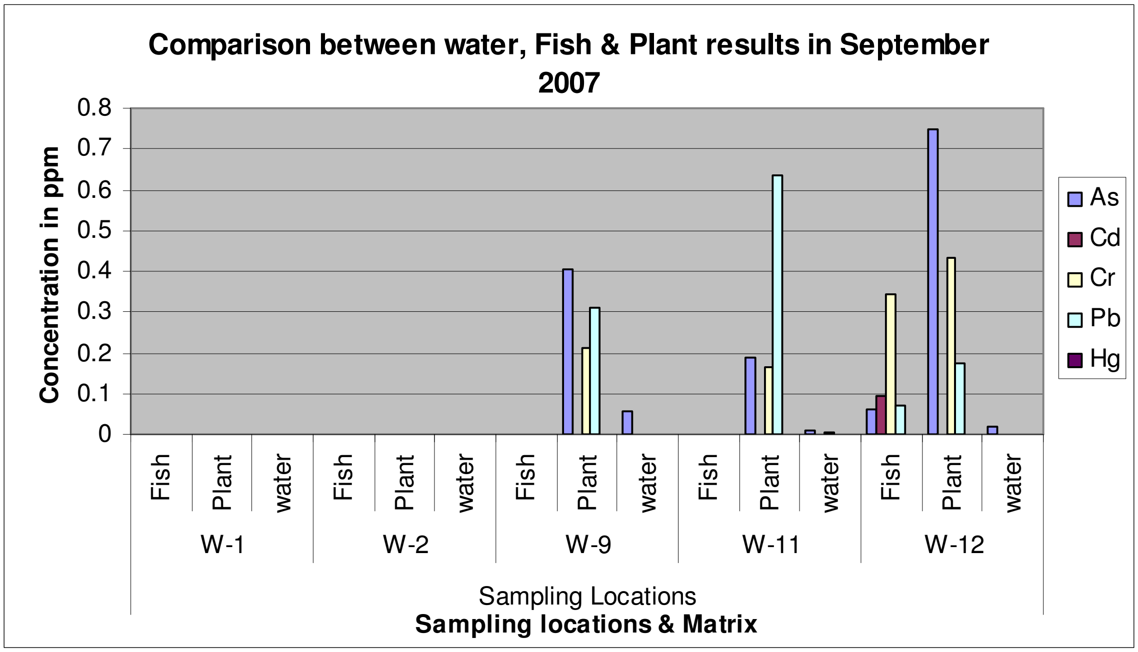

Figure 4-28, The comparison of concentration of metals in different types of samples in September 2007 sampling period

4.2.4 Bio-concentration Factor

Tables 4-29 and 4-30 show the summary bioconcentration factor in fish and plant samples. Heavy metal concentrations were compared across three locations for fish samples and five locations for plant samples. In fish samples, at sampling location W-1 and W-2, all the heavy metals were reported below detection limit < 0.05 mg/kg. At sampling location W-12 , BF of arsenic was found to be 4.77 and 2.76 for August and September months respectively. Lead was found to be 49.5. Cadmium and mercury was not detected at all sampling locations. However, there was no consistent pattern of factors were obtained for fish samples and plant samples. The highest factor was obtained for chromium at sampling location W-12 as 147 and 172 for August and September respectively where the pollution sources are at maximum level and are discussed in section 4.2.2.1.

It is observed that the BF obtained for plant samples are higher than fish samples.

For plant samples at W-12, Arsenic factors were 32 and 35 for August and September months respectively. For chromium 245 and 215 and for lead it was 70 for August. BF for plants was reported high when compared to fish samples; it may due to its absorption rate and constant exposure and absorption of heavy metals from the water media. Whereas the fish samples keep moving in the aquatic system, therefore the absorption rate also may be different depending on the concentration at the particular locations. Generally, aquatic plants can accumulate high amounts of heavy metals. In such a way, they reflect the toxicity of the water environment, and may serve as a tool for the biomonitoring of contaminated waters (e.g. Wang 1991, Sawidis *et al.* 1995, Ravera 2001, Zurayk *et al.* 2001, Cardwell *et al.* 2002). Different accumulation abilities of species more or less depend on individual plants; nevertheless, some studies pointing out differences between the groups, e.g. submerged and emergent species (Szymanowska *et al.* 1999, Al-Saadi *et al.* 2002, Cardwell *et al.* 2002).

Comparison of the heavy metal concentrations in all studied plants and fish, it was observed that highest variability for the chromium, with the maximum of 250 times bio concentration factor at location W-9 in plant samples. At W-9 arsenic BF was 12 and 7.1 for August and September months respectively. Lead BF was 185 in August. At sampling location W-11, arsenic factor was 21 and 17 for August and September respectively. For chromium, it was 80 and 55 and for lead it was 83 for the month of August.

There was no consistent correlation was observed in the two months sampling results. The heavy metals concentration of aquatic plants and fishes apparently indicates different extent of pollution levels of Sungai Pencala

The concentrations of metal in aquatic organisms vary because they reflect the net effect of two competing process, that of uptake and of depuration. The balance between these two process will depend upon the ambient water concentrations and the relative rates of the two processes. It also affected by a number of factors, which may introduce a seasonal pattern of variation. Seasonal variations in the physiological condition of aquatic organisms primarily arise from the reproductive cycle and changes in growth rate (Molles Jr, 2005). The reproductive cycle involves the maturation of the gonads and gametes and then spawning. These involve substantial changes in the balance within the organism between proteins, lipids and carbohydrates as well as body weight, water content and general condition of the organism. Period of fast growth are associated with reducing metal concentration in tissues. Low growth results in increasing tissue concentrations. There need be no change in the total body burden for these effects to be evident. These relationships resulting in seasonal variations in tissue concentrations (Mance, 1987; Mason, 1996).

4.3 Solid Waste Characterization at Sungai Pencala

4.3.1 Results and discussions

The sampling activities took placed for three months in July, September and October 2007 to determine the major solid waste categories present at each sampling point. Due to the time constrains only four categories of solid waste could be determined during the sampling activities which were plastic, metal, paper and organic solid wastes. The results for each month (in percentage) obtained for the four sampling points at Sungai Pencala for the four solid waste categories are shown in table 4-31 to 4-33. The average result is shown in Table 4-34.

Table 4-31: Percentage of Solid Waste Composition in July 2007

Sampling Point / Category	W-2	W-9	W-11	W-12
	Percentage (%)			
Plastic	80.0	8.1	71.3	24.6
Metal	0.0	0.0	2.9	0.5
Paper	20.0	1.6	8.1	2.9
Organic	0.0	90.3	17.7	72.0
Total	100.0	100.0	100.0	100.0

Table 4-32: Percentage of Solid Waste Composition in September 2007

Sampling Point / Category	W-2	W-9	W-11	W-12
	Percentage (%)			
Plastic	99.5	1.7	87.4	23.7
Metal	0.5	77.4	0.0	15.5
Paper	0.0	11.5	2.8	1.4
Organic	0.0	9.4	9.8	59.4
Total	100.0	100.0	100.0	100.0

Table 4-33: Percentage of Solid Waste Composition in October 2007

Sampling Point Category	W-2	W-9	W-11	W-12
	Percentage (%)			
Plastic	98.5	1.1	54.6	25.3
Metal	1.5	0.0	39.9	1.0
Paper	0.0	0.0	0.0	44.2
Organic	0.0	98.9	5.5	29.5
Total	100.0	100.0	100.00	100.0

Table 4-34: Average Percentage of Solid Waste Composition from July, September, and October 2007

Sampling Point Category	W-2	W-9	W-11	W-12
	Percentage (%)			
Plastic	92.6	3.6	71.1	24.5
Metal	0.7	25.8	14.3	5.7
Paper	6.7	4.4	3.6	16.2
Organic	0.0	66.2	11.0	53.6
Total	100.00	100.00	100.00	100.00

4.3.2 Solid Waste Composition at sampling Point W-2

Figure 4-29 shows the location of sampling point 2 (after KLGCC before Rimba Kiara). Figure 4-30 to Figure 4-32, show the percentages of solid waste present at this sampling point in July, September and October 2007. Table 4-34 shows the average percentage of each categories of solid waste.

Figure 4-29: Location of Sampling location No W-2

Based on the sampling activities carried out in July, September and October 2007, plastic solid waste was the major solid waste present at this location with 80, 100 and 98 percent respectively and an average of 92.6%. Organic solid waste was not found here during the three sampling activities. The geographical location of this sampling point which is situated at the upstream of Sungai Pencala may have influenced the types of solid waste found. The stream which yet to flown through highly urbanized residential, industrial and commercial areas showed the least or no percentage of paper, organic and metal solid waste. Figure 4-29 shows the sampling point W-2 to illustrate the distribution of solid waste.

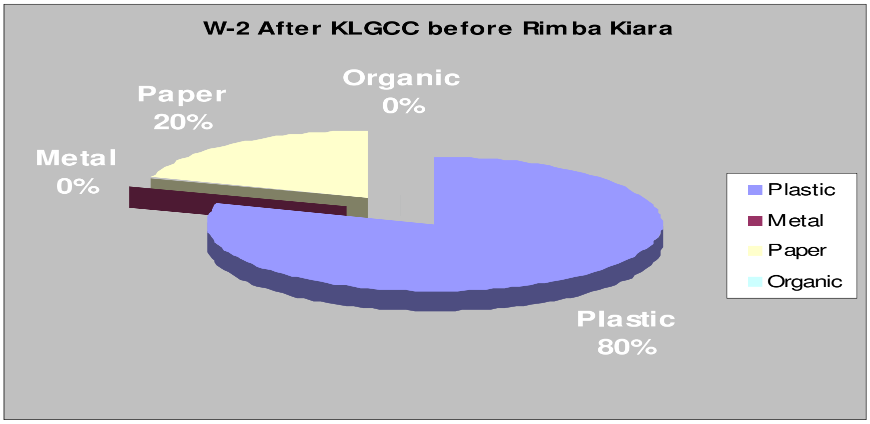

Figure 4-30: Solid waste composition for July 2007 at sampling point W-2.

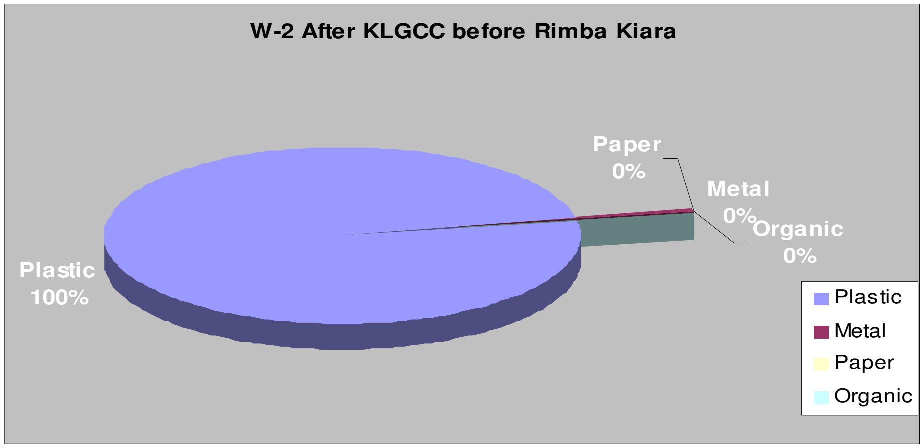

Figure 4-31: Solid waste composition for September 2007 at sampling point W-2.

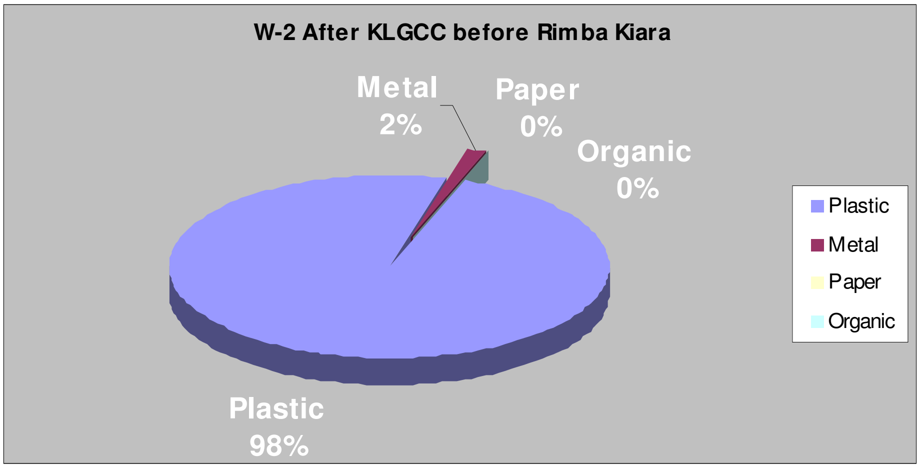

Figure 4-32: Solid waste composition for October 2007 at sampling point W-2.

From the figure 4-31 and 4-32, it is clear that plastic waste was dominant at this point and it may be due to human activities like camping, fishing or jogging activities at the Rimba Kiara Park. During heavy rainfall solid wastes tend to be flushed into river stream and seen to be floating on the river.

4.3.3 Solid Waste Composition at sampling Point W-9

Figure 4.33 shows the location of sampling point W-9 (a Tributary from Taman Aman). Figure 4-34 to Figure 4-36 show the percentages of solid waste present at this sampling point for July, September and October 2007.

Figure 4-33: Compartment of motorcycle found at sampling point W-9 was classified as metal solid waste.

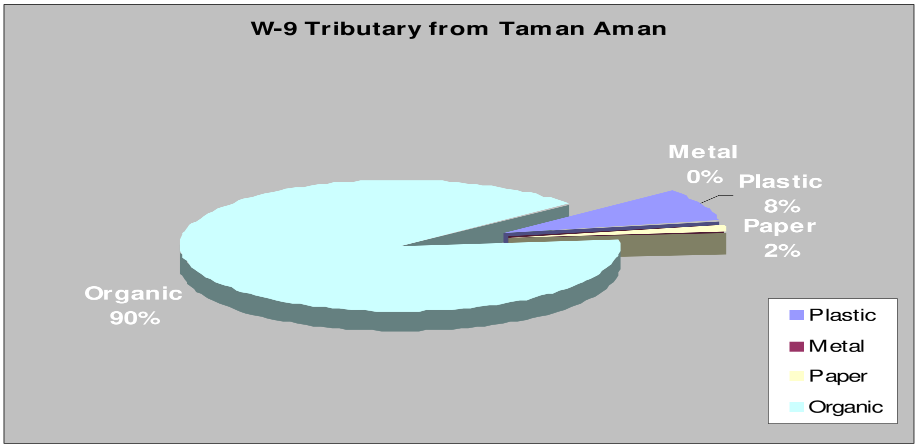

Figure 4-34: Solid waste composition for July 2007 at sampling point W-9.

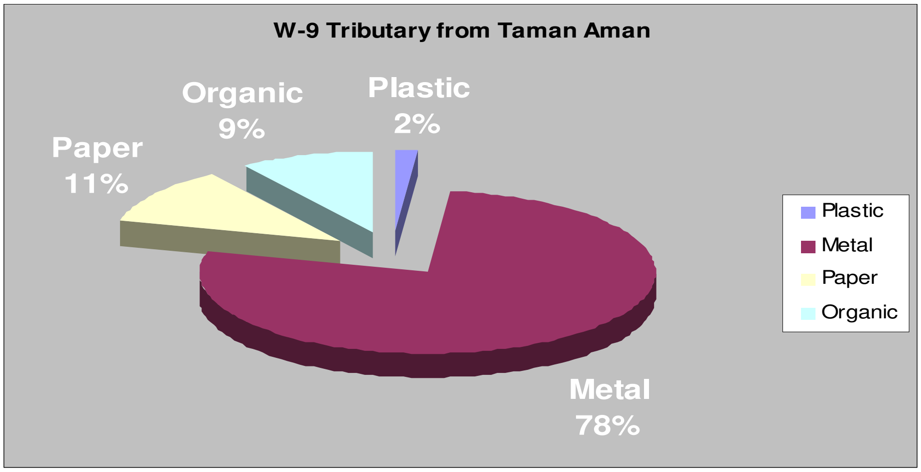

Figure 4-35: Solid waste composition for September 2007 at sampling point W- 9.

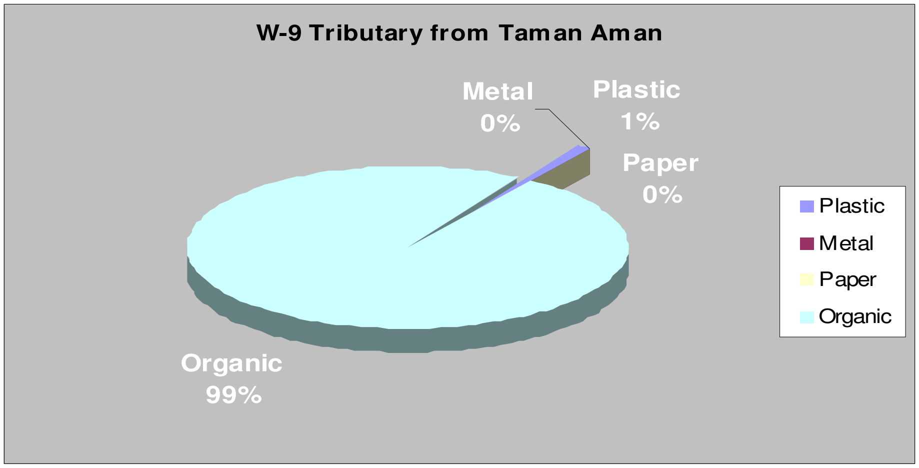

Figure 4-36: Solid waste composition for October 2007 at sampling point W-9.

Organic solid waste was found to be the major solid waste present at this location in July and October 2007 sampling activities with 90 and 99 percent respectively. Metal solid waste was not found during these two months. However, during September 2007 sampling activity, a compartment of motorcycle made of metal was found to be thrown along the bank at this point (refer to Figure 4-33) thus contributing a lot to the total mass of solid waste at this stream making metal as the major solid waste with 78 percent. Other solid waste (paper and plastic) was only found at minimum percentage during the three sampling times. Sampling point W-9 is surrounded by residential area and nursery which is located just beside the stream. This might be the reason why organic solid waste such as food and yard waste was found to be very high here. Proper solid waste handling and collection provided by Petaling Jaya City Council may be the reason why paper and plastic solid waste was least found here.

4.3.4 Solid Waste Composition at sampling Point W-11

Figure 4-37 shows the location of sampling point 11 (a Tributary from Jalan Templer/Tandang). Figure 4-38 to Figure 4-40 show the percentages of solid waste present at this sampling point for July, September and October 2007.

Figure 4-37: Sampling location W- 11 Plastic wastes from industry dumped near the sides of the river.

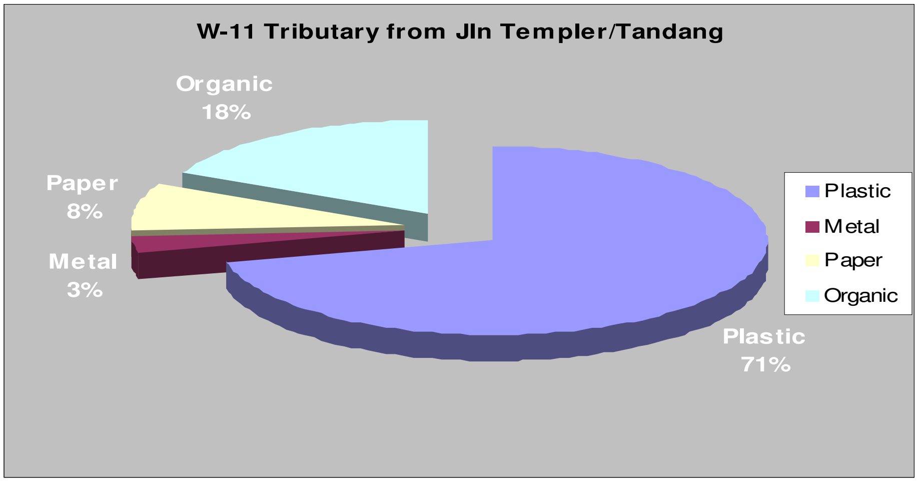

Figure 4-38: Solid waste composition for July 2007 at sampling point W-11.

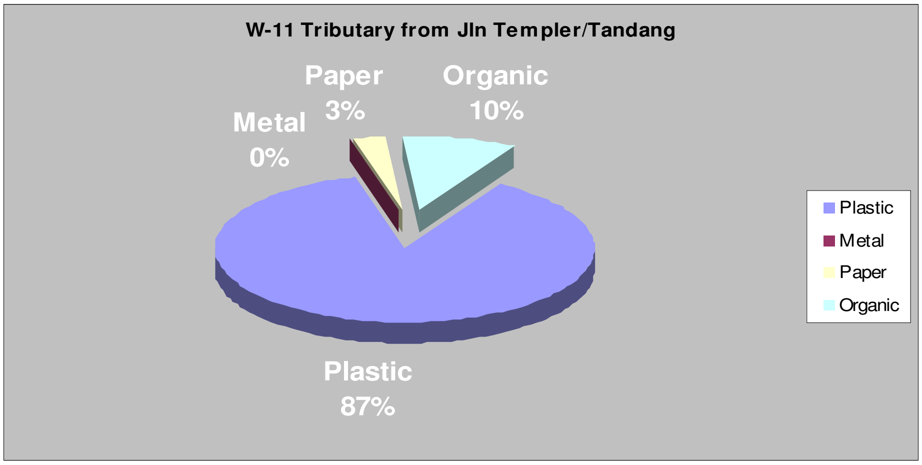

Figure 4-39: Solid waste composition for September 2007 at sampling point W-11.

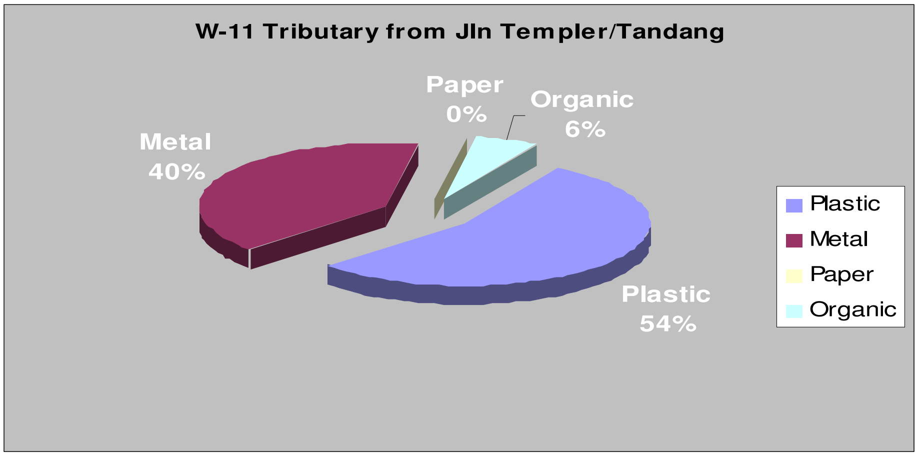

Figure 4-40: Solid waste composition for October 2007 at sampling point W-11.

During sampling activities done in July, September and October 2007, plastic solid waste was the major solid waste present at this location with 71, 87 and 54 percent respectively and with an average of 71 percent. Organic solid waste was the second highest for July and September sampling with 18 and 10 percent and decreased to only 6 percent in October. Average organic waste percentage was 11 percent. Metal solid waste was the least type found in July and September 2007 (3 and 0 percent) but increased dramatically to 40 percent in October thus recorded a 14 percent in average. Canned food and beverages were the common metal solid waste found in this month. Paper solid waste was less than 10 percent for all the three sampling times. This sampling location is situated at Jalan Templer and is well known for its industrial activities. Factories were found alongside the stream and may become the major contributor of solid waste found at this location. Figure 4-37 shows some packing materials and plastic wastes dumped along the river side of the stream which are evidence of the industrial operations and these will eventually be flushed downstream during heavy rainfall. It was also noticed that there were some food containers, plastic bottles and polystyrene packaging materials floating on the stream that contributed to high plastic waste during the three months sampling period. Small village and wet market which situated nearby may also have contributed to high percentage of plastic waste. Trading activities that involved plastic in a huge amount worsen the situation. This plastic and other solid waste often end up in the stream due to poor facilities provided by the city council.

4.3.5 Solid Waste Composition at Sampling Point W- 12

Figure 4-41 to Figure 4-43 show the location of sampling point 12 (Tributary from Sg Way) and their solid wastes pollution. Figure 4-44 to Figure 4-46 show the percentages of solid waste present at this sampling point for July, September and October 2007.

Figure 4-41: A scene at sampling point W- 12.

Figure 4-42 Different types of solid waste at sampling point W- 12

Figure 4-43: A dead rat floating on the stream at sampling point W- 12

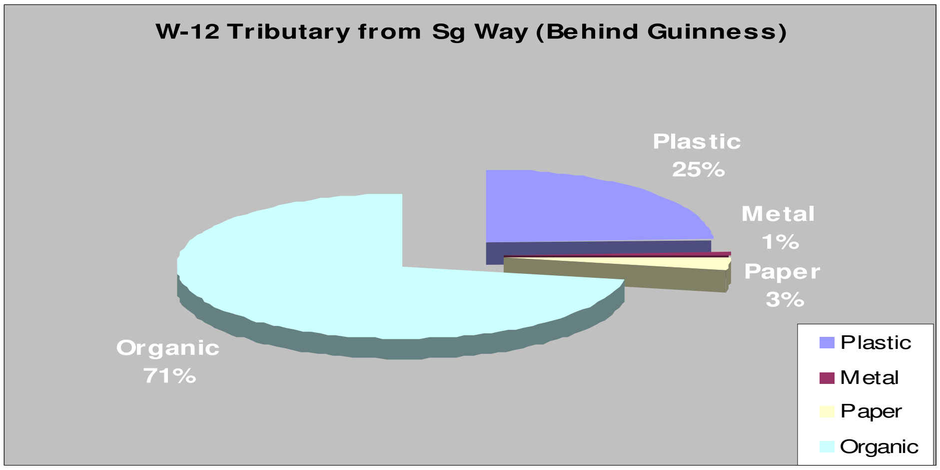

Figure 4-44: Solid waste composition for July 2007 at sampling point W-12.

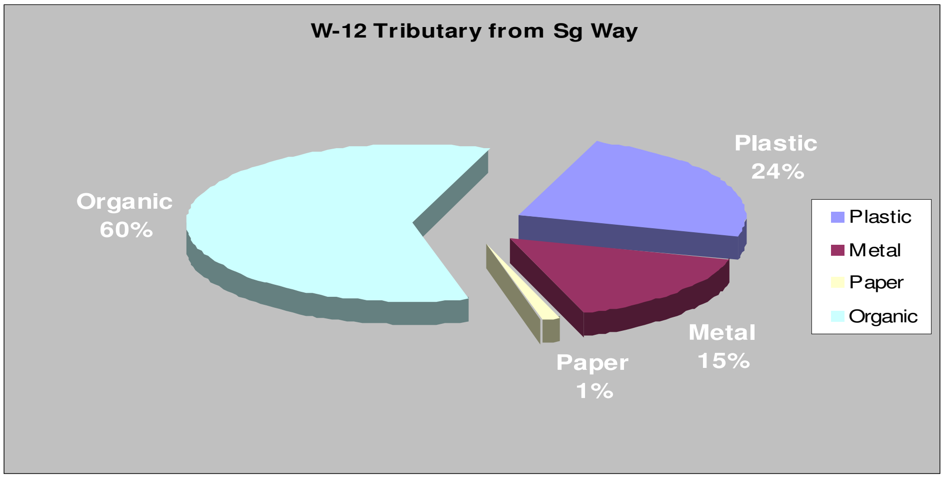

Figure 4-45 Solid waste compositions for September 2007 at sampling point W- 12.

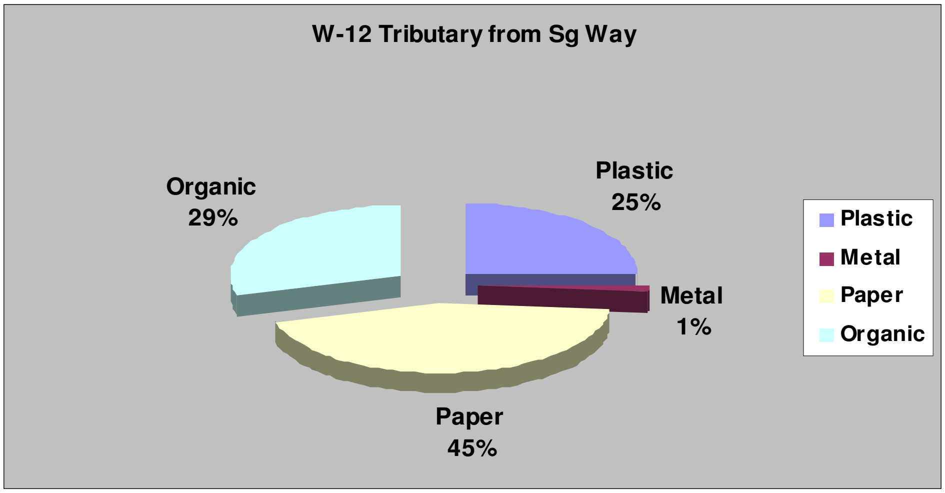

Figure 4-46: Solid waste composition for October 2007 at sampling point W-12.

The geographical location of this sampling point which is the most downstream of Sungai Pencala made this location abundance with solid waste as shown in Figure 4-42. The stream had flown through industrial, commercial, residential and even squatter's areas before entering this sampling point. This sampling point is also located close top residential, commercial and industrial areas where houses, wet markets, restaurants and school located just beside the river. From Figure 4-43, it could be seen that dead rat and dead fish were thrown into the stream which causes organic waste to be higher at this point. Organic wastes varies from 1.4 kg to 2.3 kg which consist of food, rubber, clothes and yard waste were mostly the major types of solid waste found for two consecutive sampling times in July and September with 71 and 60 percent respectively. These food wastes most probably come from restaurants or housing area where the occupants tend to throw away their food wastes conveniently into the stream. These figures significantly decreased to 29 percent in October may be due to the rain episode during this time as well as the active degradation process due to the conducive temperature and pH of the heavily polluted river. Plastic solid waste recorded constant percentage with 25, 24 and 15 percent respectively for each sampling times. Metal solid waste was high during September sampling (15 percent) while the other two months only it was recorded as 1 percent. Paper solid waste was the least types found in July and September but increased dramatically and became the major solid waste found in October sampling with a value of 45 percent. The occurrence of boxes in abundance in the stream during October sampling may be from the activities at the wet market and commercial areas located nearby.

4.3.6 Types of solid waste identified at the four sampling locations

4.3.6.1 Plastic Solid Waste

Plastic solid waste such as plastic bag, bottle and polystyrene can be harmful to environment as it cannot be degraded. Plastic bag for example took more than 100 years before it can be fully degraded (Mohkeri, 2006). Table 4-35 shows the percentages of plastic solid waste found at each sampling location during the three sampling times. The general trend of plastic solid waste is shown in Figure 4-47

Table 4-35, Plastic solid waste percentage for each month at each sampling point

location	W-2	W-9	W-11	W-12
	Percentage (%)			
July	80.0	8.1	71.3	24.6
Sep	99.5	1.7	87.4	23.7
Oct	98.5	1.1	54.6	25.3

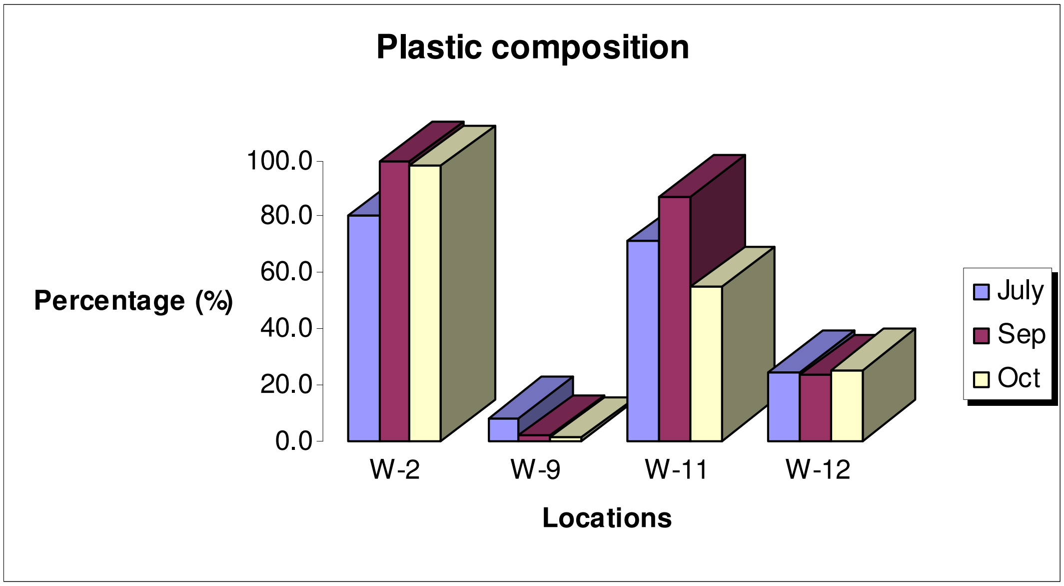

Figure 4-47: General trend of plastic solid waste at each sampling location.

Plastic solid waste was the most common type of solid waste found in Sungai Pencala. At each sampling point in each month of sampling, plastic solid waste never fail to occur. In fact, at sampling location W- 2 and W-11, plastic was the major solid waste identified. Plastic bag, bottle and polystyrene were the most types of plastic solid waste found. Plastic often ends up in the stream as a result of human negligence and lack of awareness that plastic might be harmful to aquatic life.

From the Figure 4-47, it can be noted that locations W-2 and W-11 seem to have higher percentage of plastic waste content with a value of 92.6 at W-2 and 71.0 percent at W-11. Sampling point W-2 which is near KLGCC and Rimba Kiara park may involved human activities like fishing, jogging and camping which resulted in plastic wastes accumuling on the surface of the stream. Sampling point W-11, which is a tributary from Jalan Templer/Tandang, is surrounded by industrial area and therefore the plastic wastes could have originated from the industrial operations. At sampling location W-9, a tributary from Taman Aman only 3.6 percent plastic waste was collected. This area falls under Petaling

Jaya City Council. There were no significance contributions of plastic waste at sampling location W-9. At sampling location W-12, which is a tributary from Sungei Way, 24.6 percent of plastic solid waste was collected and it could be from the residential area. At each sampling trip, it was observed that plastic waste, rubber materials, and some household items were thrown along the sides of the stream and during heavy rain fall all these wastes would be flushed in to the river and get stagnated onto the river.

Depending on their form they can either be ingested by the aquatic life, causing internal organ failure, or they can cause a slow strangulation (Newton, 1990). The abundance of plastic in the river or stream is harmful to aquatic habitat and wildlife, and in turn affects land-based ecosystems. In the 1980s it was estimated that plastic rubbish caused the deaths of over 100,000 aquatic mammals and sea turtles a year in the North Pacific alone. Plastics have been found in the digestive tracts of over 100 species of seabirds. In fact, by 1998, the Marine Mammal Commission (MMC) reported that marine debris had affected at least 267 animal species around the world. Over time, plastic breaks down into increasingly smaller pieces, eventually forming a plastic dust that may be consumed by filter feeders and enter the food chain. This has potentially negative consequences to our health (MMC, 1998).

4.3.6.2 Metal Solid Waste

Metal solid waste can be in the form of ferrous, non ferrous and bimetallic (GVRD, 2003). According to Mohkeri, 2006 from Global Environment Centre (GEC), metal or to be precise beverage tin took 200-500 years to degrade. Soft drink and food container are the best example of metal solid waste. These types of metal were commonly found in Sungai Pencala during three sampling activity. At sampling location W-9 in September sampling, a part of motorcycle body was found in the stream as shown in Figure 4-33, thus making it the major solid waste found in that particular month.

Table 4-36 and Fig 4-48 shows the general trend of metal solid waste at each sampling point at three sampling times.

Table 4-36: Metal solid waste percentage for each month at each sampling point

Locations	W-2	W-9	W-11	W-12
	Percentage (%)			
July	0.0	0.0	2.9	0.5
Sep	0.5	77.4	0.0	15.5
Oct	1.5	0.0	39.9	1.0

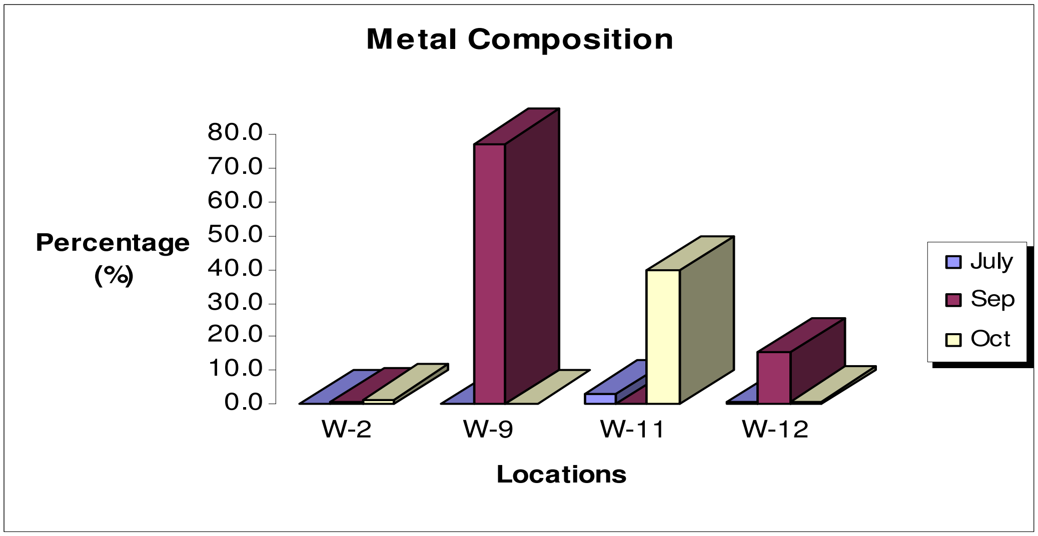

Figure 4-48: General trend of metal solid waste at each sampling location

At sampling location W-2 (after KLGCC before Rimba Kiara park) there was only an average of 0.7 percent metallic waste collected. At location W-11, a tributary from Jalan Templer/Tandang, there was 14.3 percent of metallic waste such as soft drinks can, which was thrown into the river and it could be due to improper disposal or negligence of industrial workers. Sampling location W-12, a tributary from Sungei Way is mainly surrounded by residential area, restaurants and commercial activities. The major metallic waste found here were soft drinks cans and some household containers and this could be the reason for 5.7 percent of metallic waste at this location. Metal material itself might be hazardous to aquatic life due to chemical leaching of this material into the stream.

4.3.6.3 Paper Solid Waste

Newsprint, wax paper, paper and magazine are the types of paper solid waste that end up in the river or stream. Paper solid waste, however, only took approximately 3 weeks to degrade thus it may not have significant impact on the environment including stream. Table 4-37 shows the percentage of paper solid waste at each sampling point during the three sampling times. The general trend is shown in Figure 4-49.

Table 4-37: The percentage of paper solid waste for each month at each sampling point.

Locations	W-2	W-9	W-11	W-12
	Percentage (%)			
July	20.0	1.6	8.1	2.9
Sep	0.0	11.5	2.8	1.4
Oct	0.0	0.0	0.0	44.2

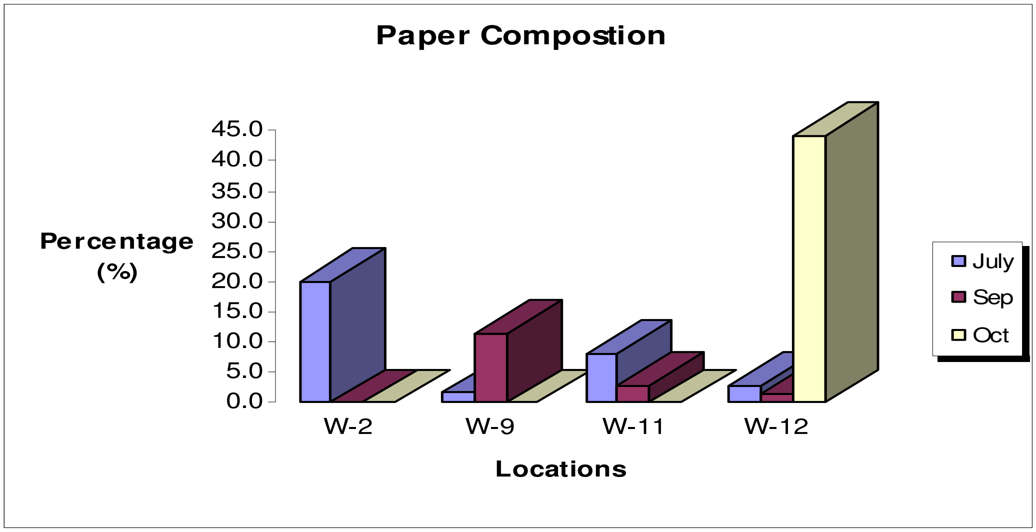

Figure 4-49: General trend of paper solid waste at each sampling location

Paper wastes were found to be minimal at all sampling locations except at sampling location W-12. A total of 44 percent paper was collected in October which was the highest reading ever recorded. This sampling point is located at residential area where there is high possibility that the paper wastes originated from the housing area.

4.3.6.4 Organic Solid Waste

Organic solid waste is anything solid which have carbon constituent in it. Food, garden or yard, rubber and wood pallet are the example of organic solid waste. Table 4-38 shows the results of three sampling times. Figure 4-50 shows the general trend at each sampling times.

Table 4-38: Organic solid waste percentage for each month at each sampling point

Locations	W-2	W-9	W-11	W-12
	Percentage (%)			
July	0.0	90.4	17.7	72.1
Sep	0.0	9.5	9.8	59.4
Oct	0.0	98.9	5.5	29.5

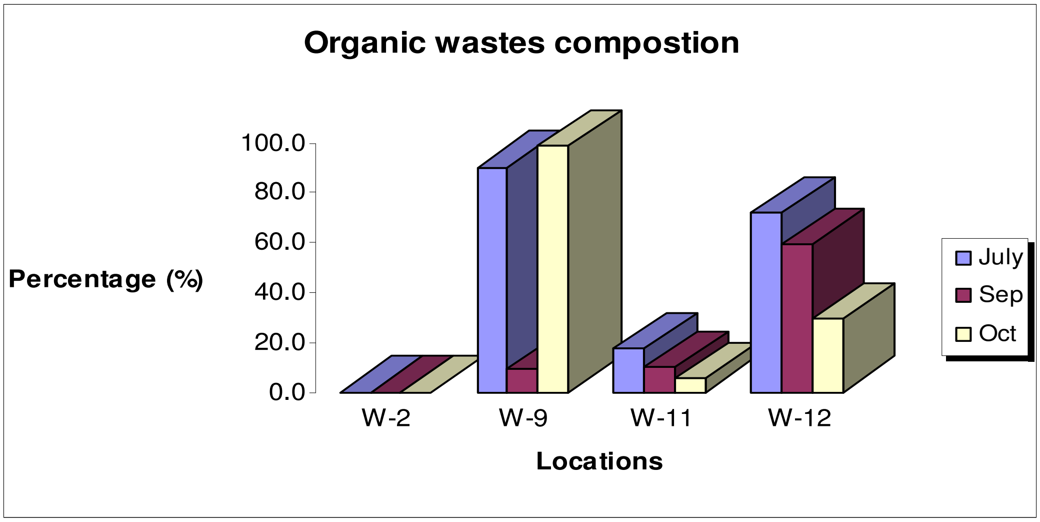

Figure 4-50: General trend of organic solid waste at each sampling location

Figure 4-50, indicates that there are minimum contribution of organic waste from sampling location W-2 as this location is very near to KLGCC and park area where proper maintenance at these locations could resulted the minimum organic wastes. Location W- 11 (a tributary from Jalan Templer/Tandang) with high industrial activity was found to have minimal generation of organic wastes, whereas at sampling location W-9 (a tributary from Taman Aman) organic wastes was recorded to be at the highest with a value of 66 percent. This could be due to the disposal of food wastes and kitchen wastes from the surrounding residential area. The same situation goes to sampling location W-12 (a tributary from Sungai Way) where this sampling point is surrounded by residential and restaurants. Average of 53 percent of organic wastes was collected at this location. Figure 4-33 shows the dead rat found to be floating on the stream. This picture was taken at location W- 12 during September 2007 sampling. Kitchen waste and rotten food like fish and fish wastes were also collected during sampling. These are the possible sources of high level organic wastes at these two locations.

Organic waste which is one of the common solid wastes in Malaysia can cause chemical and biological impacts on rivers and streams (Malaysia Country Report 2001). Among the many impacts are interfering with the establishment of aquatic plants, affecting the reproductive behavior of fish and other animals, and depleting the dissolved oxygen levels as the wastes decompose (Chiras, 1998). The BOD will be higher as well due to the leaching of organic materials from the solid waste (Yusoff, 1997). A good example is food waste where it contains organic material, when entering the surface water the contents will leach out.

4.4 Correlation between water quality parameters

Figure Shows 4.-51, Correlation between chemical oxygen (COD) and biological oxygen demand results for water samples analyzed. The data seems to have good correlation and the R-square value (correlation coefficient) on the chart is 0.843.

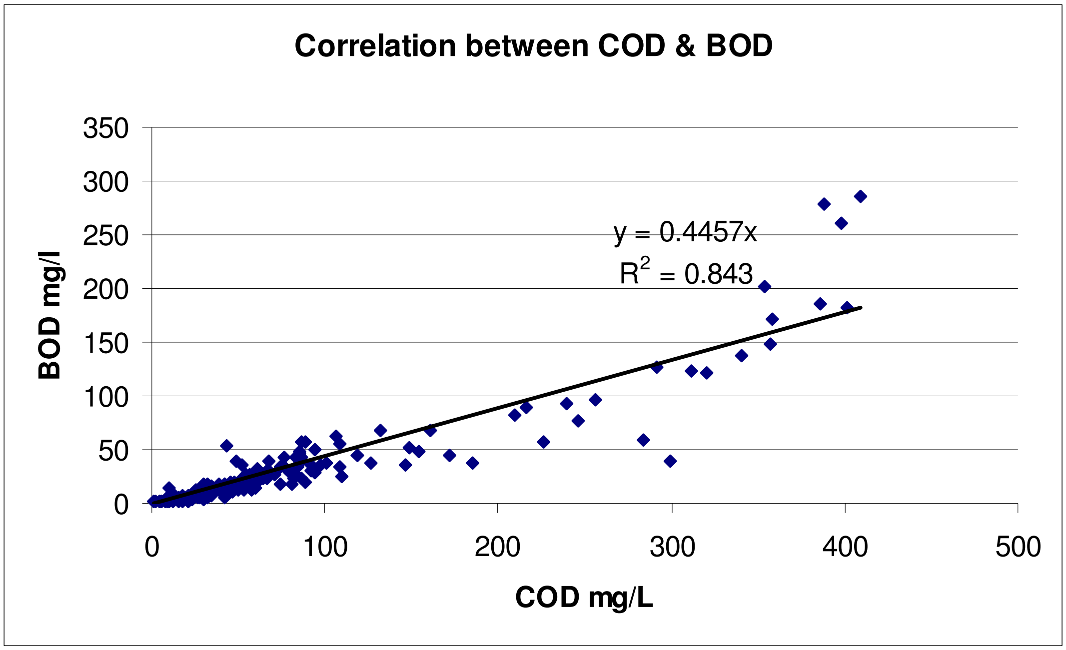

Figure 4-51 – Correlation between COD and BOD for water samples

Figure 4-52, shows that total suspended solids (TSS) and chemical oxygen date does not correlate much as the R square value is 0.1704. Whereas the conductivity and total dissolved solid shows good correlation as R square value 0.9773.

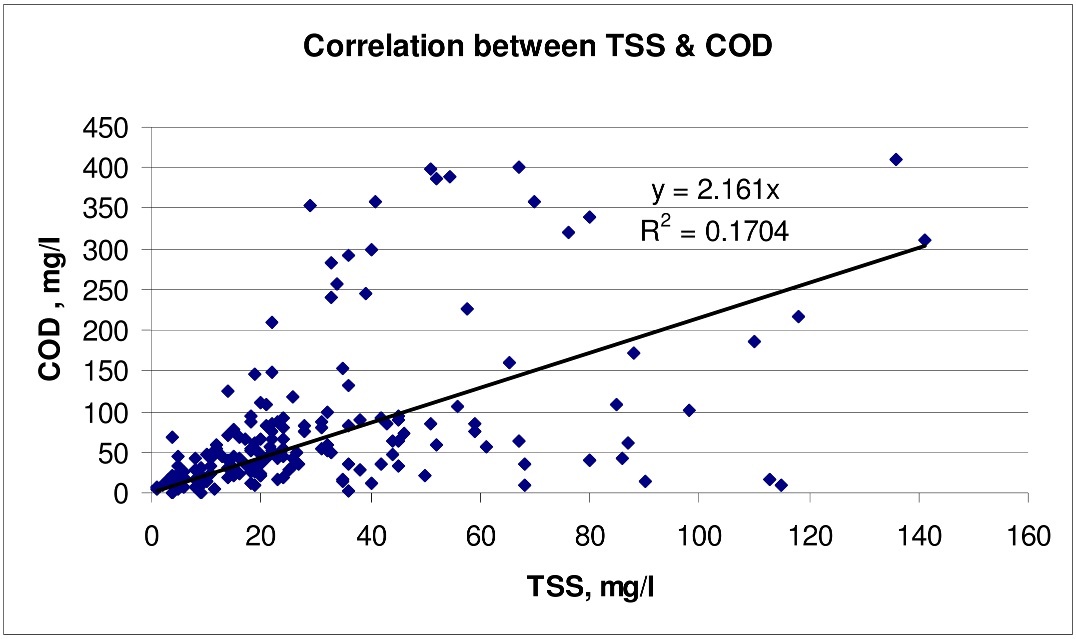

Figure 4-52 – Correlation between COD and TSS for water samples

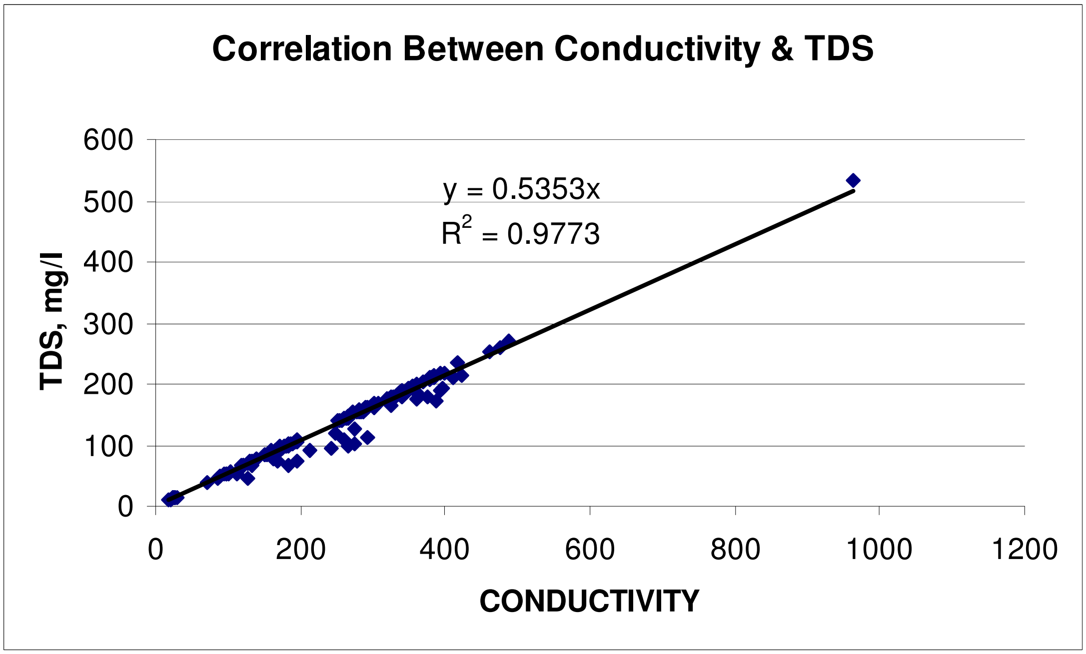

Figure 4-53 – Correlation between conductivity and TDS for water samples

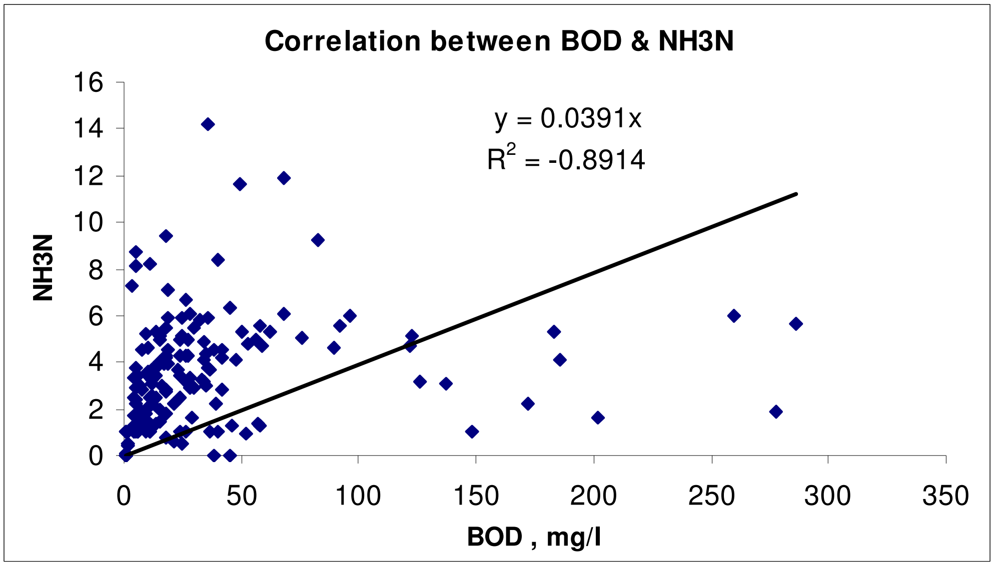

Figure 4-54 – Correlation between BOD and ammoniacal nitrogen for water samples

From the figure 4-54, shows negative correlation between BOD and ammoniacal nitrogen as the R square values is found to be – 0.8914.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

The purpose of this study is to determine the water quality of Sungai Pencala and to identify the concentration of selected parameters along Sungai Pencala. 14 sampling points were selected to represent the water quality of Sungai Pencala.

The study measures water quality for a 12 months period for fourteen locations along Sungai Pencala. In addition to water quality parameters, the study includes detailed background information about the solid wastes and bioaccumulation on aquatic habitat because this links to the chemistry signature of the environment.

From this study, it is found that the concentrations of most of the selected parameters were high at sampling points which was located near residential areas and industrial areas (point W-11 and W-12) for TSS, TDS, NH_3-N, BOD_5, COD, conductivity and E Coli. Meanwhile the lowest level of pollution was observed at sampling points upstream of the river i.e W-1 and W-2.

Temperature, pH and conductivity of Sungai Pencala, were falls under class I of DOE Standard. Dissolved Oxygen concentrations fall under class III for some of the sampling points W-3, W-9, W-11 while W-12 falls under class IV.

The turbidity concentration of Sungai Pencala falls under class III of DOE Standard and only sampling point W-1 falls under class I. TSS of Sungai Pencala falls under class III while TDS in September and November fall under class I but falls under class II of DOE Standard in October.

Besides that, the results of BOD_5, COD, DO, and TSS fall under class III and IV for some of the sampling points. For BOD, the upstream points fall under class II, midstream points fall under class II while the downstream points fall under class IV which is not suitable for most of activity. At point W-11 and W-12, the COD fall under class V due to the effluent discharge into the stream. The result of NH_3N falls under class V of DOE standard.

From these results, it can be concluded that the water quality of Sungai Pencala was not suitable for activities such as water supply and irrigation. For upstream points the water is suitable for recreation activities but for some points at midstream and downstream are not suitable for such activities.

From the bioaccumulation study on fish samples, at W-1 and W-2, all the heavy metals were reported to be below detection limit < 0.05 mg/kg. At sampling location W-12, arsenic BF was found to be 4.77 and 2.76 for the months of August and September respectively. Lead was found to be 49.5. The highest factor was obtained for Chromium at 147 and 172 for August and September respectively. Cadmium and mercury were not detected at all sampling locations. The highest factor was obtained for chromium at sampling location W-12 where the pollution influents were are at maximum level and are discussed in section 4.2.1 and shown in Figure 4.3.

For plant samples, it was observed that the BF obtained were higher than fish samples. At W-12, arsenic factors were 32 and 35 for August and September respectively. For chromium 245 and 215 and for lead it was 70 for the August. BF for plants was higher when compared to fish samples; it may due to its absorption rate and constant exposure and absorption of heavy metals from the water media whereas the fish samples keep moving in the aquatic system, therefore the absorption rate also may be different depending on the concentration at the particular locations.

Based on solid wastes data, it is observed that plastic solid waste was the major solid waste present at the two sampling locations selected, viz which were sampling point W-2 and W-11. While organic waste was dominant at sampling point W-9 and W-12. It can be concluded that the surrounding area and activities influence the type of solid waste present at those sampling locations. Organic wastes which are mostly yard waste and kitchen wastes were found in highest percentage at sampling point W-9 and W-12 where it is surrounded by residential and commercial areas.

From these studies, it can be concluded that the deterioration of river water is obviously a serious issue to be discussed. Deterioration of river water also causes destruction to the aquatic ecosystem. The pollutions which originated mainly from human activities namely industrialization and urbanization put solid waste as one of the main culprit towards deterioration of river water quality. However, other sources including sewage and industrial discharge also contribute towards the degradation of Sungai Pencala.

The scenario of pollutants level in the Sungai pencala shows that the river needs a better management of the environment and the development to provide ecosystem services, suitable for the support of healthy aquatic life. In addition to providing better management of Sungai Pencala, increase public awareness and education about the significance of water quality to our community will help to preserve the ecosystem.

5.2 Recommendations

There is a need for a better planning system to avoid deterioration in the Sungai Pencala catchments. Within the limits of this research, the following were concluded and recommended from this study

- Sewage should be treated to higher standards and discharged directly into the rivers. The establishments of these standards need further research.
- The high levels deterioration of the river could be due to industrial discharges and runoff from urban areas. Industrial pollution should be controlled by stricter regulations accompanied with enforcement.
- Further systematic investigations are required to ensure sustainable development in the river for the betterment of man kind.

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