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HEALTH RISK ASSESSMENT OF HEAVY METALS IN BERTAM RIVER, CAMERON HIGHLANDS

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ABSTRACT

HEALTH RISK ASSESSMENT OF HEAVY METALS IN BERTAM RIVER, CAMERON HIGHLANDS

NUR FASIHAH BINTI ZULKIPLI

Introduction: Heavy metals in water pose acute and chronic health risks to adult and children. To date, the health risk assessment (HRA) in heavy metal ingestion especially through water in Bertam River is still limited **Objectives**: To determine the physicochemical properties and the concentration of heavy metals (Zinc, Cadmium, Lead, Chromium, and Copper) in the Bertam River, Cameron Highland, to compare with NDWQS and to perform HRA among children and adult in Bertam River, Cameron Highlands. **Methodology**: Water sample were collected at 15 cm depth from the surface of the river water following the grab method. Samplings were collected using HDPE bottles for COD test and amber glass bottles for BOD test. For heavy metal, samples were collected were sample using HDPE bottles and acidified immediately with 3 ml nitric acid (69%) before the HDPE bottles sealed. All samples were stored in cooler box filled with ice packs to keep temperature below 4°c before transferring to the laboratory. Physicochemical parameters of water quality were measured in situ for pH, salinity, total dissolved solid, and turbidity using portable YSI (model 6600-M) multisensory probe. Heavy metals were detected using inductively coupled plasma mass spectrometry. The HRA was calculated using USEPA method. **Results and Discussion**: For the outcome, all parameters are within the NWQS except for turbidity (234.74$\pm$257.28 NTU) and Lead concentration (0.009$\pm$0.011 mg/L).There are significance difference between upper and lower of the Bertam River for turbidity ($p<0.05$). Findings show all the heavy metal except for Cd was positively correlated with turbidity, Cr ($r=0.996$), Cu ($r=0.649$), Pb ($r=0.987$), Zn ($r=0.86$). As for health risk in this study, all heavy metal in this study did not show any significant health risk as the HQ is less than 1 for non-carcinogenic risk and the carcinogenic risk did not exceed the acceptable risk. **Conclusion**: Based on the findings, the concentration of all heavy metals did not posed any significant risks to adult or children.

Keywords: Heavy metal, Health Risk Assessment, Water Quality

ABSTRAK

PENILAIAN RISIKO KESIHATAN TERHADAP LOGAM BERAT DI SUNGAI BERTAM, CAMERON HIGHLANDS

NUR FASIHAH BINTI ZULKIPLI

Pendahuluan: Logam berat dalam air menimbulkan risiko kesihatan yang teruk dan kronik untuk dewasa dan kanak-kanak. Setakat ini, penilaian risiko kesihatan dalam pengambilan logam berat terutamanya melalui air di Sungai Bertam masih terhad.**Objektif:** untuk menentukan sifat-sifat fizikokimia dan kepekatan logam berat (zink, kadmium, plumbum, kromium, dan tembaga) dalam Sungai Bertam, Cameron Highland, untuk membandingkan dengan Standard Kualiti Air Minuman Negara untuk Malaysia dan untuk melaksanakan penilaian risiko kesihatan kalangan kanak-kanak dan dewasa di Sungai Bertam, Cameron Highlands. **Metodologi:** Sampel air telah dikumpulkan pada 15 cm kedalaman dari permukaan air sungai mengikut cara merebut. Persampelan telah dikumpulkan menggunakan botol HDPE untuk ujian permintaan oksigen kimia (COD) dan kaca amber botol untuk ujian permintaan oksigen biokimia (BOD). Untuk logam berat, sampel telah dikumpulkan sampel adalah menggunakan botol HDPE dan berasid serta-merta dengan 3 ml asid nitrik (69%) sebelum botol HDPE dimeterai. Semua sampel yang disimpan di dalam kotak sejuk dipenuhi dengan pek ais untuk mengekalkan suhu di bawah 4°C sebelum memindahkan ke makmal. parameter fizikokimia kualiti air telah diukur di situ untuk pH, jumlah dibubarkan pepejal, dan kekeruhan menggunakan mudah alih YSI (model 6600-M).Logam berat dikesan menggunakan induktif ditambah spektrometri jisim plasma. Penilaian risiko kesihatan telah dikira menggunakan kaedah USEPA. **Keputusan dan Perbincangan:** Untuk keputusan, semua parameter yang berada dalam Standard Kualiti Air Negara untuk Malaysia kecuali kekeruhan (234.74±257.28 NTU) dan kepekatan plumbum (0.009±0.011 mg/L). Terdapat perbezaan yang signifikan diantara kekeruhan ($p<0.05$) di hulu dan hilir Sungai Bertam Hasil. Kajian menunjukkan semua logam berat kecuali kadmium korelasi positif dengan kekeruhan, Cr ($r=0.996$), Cu ($r=0.649$), Pb ($r=0.987$), Zn ($r=0.86$).. Bagi risiko kesihatan dalam kajian ini, semua logam berat dalam kajian ini tidak menunjukkan apa-apa risiko kesihatan yang ketara kerana Hazad adalah kurang daripada 1 bagi risiko bukan karsinogen dan risiko karsinogenik tidak melebihi risiko yang boleh diterima. **Kesimpulan:** Berdasarkan kepada dapatan kajian, kepekatan semua logam berat tidak menimbulkan apa-apa risiko yang besar kepada orang dewasa atau kanak-kanak.

Kata kunci: Logam Berat, Penilaian Risiko Kesihatan, Kualiti Air

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LIST OF ABBREVIATIONS

USEPA	United States Environmental Protection Agency
WHO	World Health Organization
ADD	Average Daily Dose
HQ	Hazard Quotient
RfD	Reference Dose
RAIS	The Risk Assessment Information System
LADD	Lifetime Average Daily Dose
CSF	Cancer Slope Factor
CDI	Chronic Daily Intake
ISO	International Standard Organization
APHA	American Public Health Association
TDS	Total Dissolved Solid
COD	Chemical Oxygen Demand
BOD	Biological Oxygen Demand
Zn	Zinc
Cd	Cadmium
Cr	Chromium
Cu	Copper
Pb	Lead
BW	Body weight
HI	Hazard Index
kg	Kilogram
ICPMS	Inductively Coupled Plasma Mass Spectometry
DOE	Department of Environment

CHAPTER 1

INTRODUCTION

1.1 Background

A system comprising both the main course and the tributaries is known as river. Basically, river carrying the one-way flow of a significant load of matter from dissolved and particulate phases either or both from natural and anthropogenic sources (Shrestha and Kazama, 2007). River is the most important source of water for human life and the other organism as it serves many functions such as essential supply of drinking water, providing water for domestic, hydropower generation, agricultural and industrial demands. At some part of Malaysia, river also serves as a part of the rainforest ecology and also supplying an aesthetic view (Gasim et al., 2009).

As time passes, the quality and the availability of water from the river became deteriorated due to some reasons such as increasing number of population and urbanization (Wu and Tan, 2012). To determine the water quality, the parameter that should be considered is the physical, chemical and biological characteristics of the water (Hambright et al., 2000).

There are two types of water pollution sources which are known as point and non-point sources (Hashim et al., 2005). Point sources are easily identified because it is identified as the all dry weather pollutants that enter the river or stream through channel or pipes. The pollutant concentration for the point sources pollution can be easily measured through in-situ and ex-situ methods (EPA, 1997). For non-point sources, it had been recognized in the mid-1960s and initially it had been identified as a source of pollution that is entirely related with storm water and runoff. Thereafter, non-point pollution expanded to encompass all forms of diffuse pollutants and it is defined as any contaminants of surface, subsurface soil and water resources that are diffused in nature which is the point location cannot be traced easily (Eisakhani et al., 2011).

The area of Cameron Highlands is drained by eight rivers and 123 tributaries. There are three main rivers that have major functions in Cameron Highlands which are Bertam River, Telom River and Lemoi River (Eisakhani and Malakahmad, 2009). Bertam River cover an area of 73 km2 and play significant key role in Cameron Highlands as it provide an essential supply of drinking water for the population (Gasim et al., 2009). Besides, Bertam River also provides irrigation water for local cultivation activities and also for hydroelectricity generation (Khalik et al., 2012). In addition, Bertam River also flowing into the TNB Ringlet Reservoir or also called as Sultan Abu Bakar Dam was commissioned in 1965 (Tenaga Nasional Berhad, 2006)

The Upper-Bertam catchment act as the important water catchment and the Upper-Bertam catchment also supply water for agriculture and urban area. To prevent erosion and soil runoff in agriculture , the slope should be less than 25 and of a capable soil type ,almost 45% of the agriculture land in the Cameron Highlands is indiscriminately used for agricultural purposes, this is because it is already exceeds these basic concepts (Ent and Termeer, 2006).

The primary routes of metal accumulation in humans are through the ingestion of contaminated drinking water, vegetables, fruits, fish and soil (Miller et al., 2003). Enrichment of heavy metals induces toxic effects on living organisms when they exceed certain concentration limits (Macfarlane and Burchett, 2000).

1.2 Problem Statement

The main water supply resources in Peninsular Malaysia (90%) are from the highlands. Cameron Highlands being one of the major highlands areas in Peninsular Malaysia that plays a vital role. Cameron Highlands is drained by three major rivers namely Bertam River, Telom River, and Lemoi River. The main tributaries in Upper Bertam namely Sungai Burung, Sungai Ruil, Sungai Jasar, Sungai Uluh and Sungai Batu Pipih joint with the main course of Upper Bertam River at different locations before flowing into Ringlet reservoir (Rasul et al., 2015).

The nature of water is influenced by human activities and is declining because of the rise of urbanization, population development, environmental change and other factors. The resulting water contamination is a genuine danger to the well-being of both the Earth and its population. Based on the previous study, there is evidence that local communities were suffering from a variety of health problems that could be a direct or indirect result of the water pollution. Skin problems is example can be related to the high pH of the water, which could certainly irritate the skin and result in sores (Halder et al., 2015).

Previous study shows that Bertam River was heavily polluted from the agriculture activity in Cameron Highland. For example, Rasul et al. (2015) reported high turbidity value with the mean value of 88.63 NTU and ranged between 0.01 to 392.89 NTU. Urban development also cause high BOD load (3.56×108 m3/yr) in the area.

Agricultural activities and deforestation contribute the highest annual loads for phosphorus (6.91×104 kgP/yr) and nitrogen (2.50×105 kgP/yr) in Cameron Highland (Eisakhani et al., 2011).

Besides that, high agriculture runoff as much as 5.31×107m3 /yr in Cameron highland had been reported in the previous studies. According to Chantal et al, (2006), only 20% of water from the Bertam River is provide for the drinking water and another 80% of total clean water supply is utilized by the agricultural industry. Only 3.292 ha from the total of 71.218 ha of Cameron Highlands that are suitable for agriculture but the use of agricultural land had exceed to 5.705 ha (Eiksakhani et al., 2011).

A study conducted by Munisamy R. et al., (2013) found out that 11.5% of population in Kuala Terla and Blue Valley farming villages, Cameron Highlands use river water for their household chores. Shah et al., (2007) stated that malnourishment and diseases such as abdominal pain, anorexia, cardiovascular diseases, immune dysfunction, hypertension, liver and kidney related disorders, as well as various kinds of cancers could be caused not only by nutrient deficiency, but also by excessive intake of heavy metals in contaminated food and drinking water.

Based on the previous study, the highest annual runoff in Cameron Highlands was created by deforestation, 3.56×108 m3/yr followed by urban development, 1.46×108 m3 /yr. Besides that, Cameron Highlands known as the centre for vegetable farming in Malaysia where farmers have been using heavy doses of various types of fertilizers and pesticides (Khairiah et al. 2006). Kartel et al. (2006) stated that levels of Magnesium (Mg) and Copper (Cu) were high in soil samples from Ringlet and Tanah Rata, Pahang. This is because, that part of Bertam River is indirectly having an additional sediment inputs from agriculture, farming and industries in the upstream areas of small rivers (Haron et al., 2015).

Water quality can be seen as an indicator of environmental quality of an area since deterioration in water quality can be a direct outcome of non-sustainable development. From this study, the main cause for the degradation of water quality can be known. By getting through to the root of causes, we can overcome the water quality problem in Bertam River. It is important to make sure that the concentration of other heavy metals present is safe as what is addressed by the guideline. The physicochemical properties of water also should be monitor to make sure it is always below the limit that had been provided from the National Water Quality Standard. This is because the amount of heavy metals and the physicochemical of water pose an acute and chronic disease to the population. The absence of the latest study on heavy metals and physicochemical properties of Bertam River propels the need of this study. Therefore, it is important to assess the water quality by concentration of the heavy metals and the physicochemical properties of Bertam River.

1.3 Research Justification

Cameron Highlands had been identified as major highlands that play a vital role to supply water to the area of Peninsular Malaysia. The area of Cameron Highlands is drained by three major rivers which are known as Bertam River, Telom River and Lemoi River (Van, A. and Termeer C, 2005). Since there is intensive agriculture and urbanization causes pollution problems in the most vulnerable part of the catchment of Bertam River, a research to address the water quality issue in Bertam River should be conducted. This is to know the current status of water quality resulted from intensive agriculture activity in this area.

In addition, the health risk assessment (HRA) in heavy metal ingestion especially through water in Bertam River is still limited ,so, HRA important to be conducted to estimate the potential of adverse effect in the population. From this study, the population in the research area will be emphasized about the health risks posed by the different types of heavy metals that present in the water. This is because the amount of heavy metals can pose an acute or chronic disease to the population.

Next, it hopes that all the results and information obtained from this study can be used as a baseline study or reference in Malaysia, especially in water quality field. Besides that, the findings of this study can also be used to educate all the responsible person to be more considerate about the potentially harmful effect of throwing all the waste into the river.

1.4 Conceptual Framework

There are two dependent variables in this study; physicochemical properties and concentration of heavy metals. There are five parameters that include in this study which are pH, total dissolved solid, chemical oxygen demand, biological oxygen demand and turbidity. For heavy metals, there are five types of heavy metals that included in this study which are zinc, cadmium, lead, chromium, and copper. The dependent variable of this study would be the health risk assessment in Bertam River, Cameron Highlands.

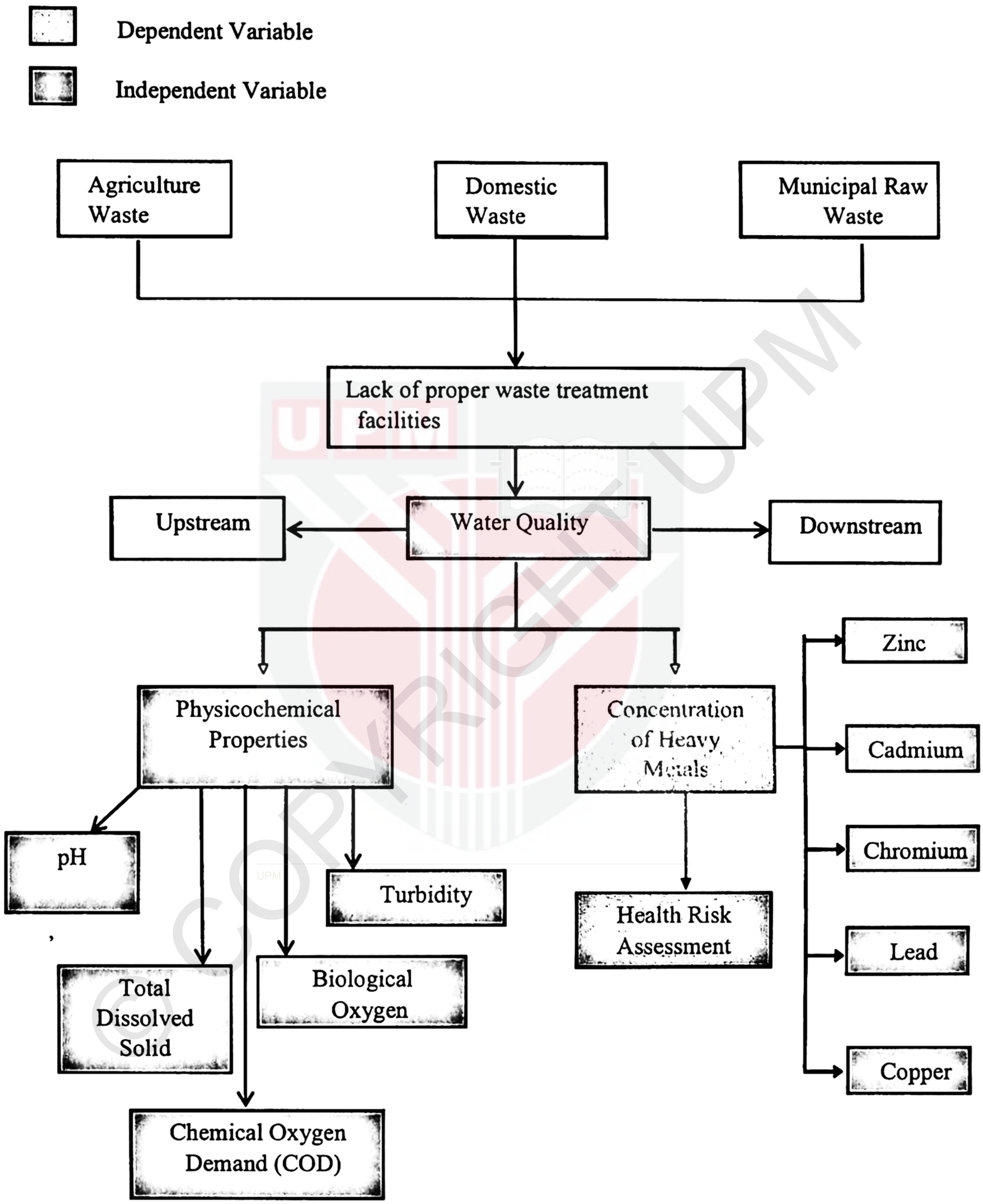

Figure 1: Conceptual framework of the study

1.5 Definition of Terms

1.5.1 Conceptual Definition

i. Heavy Metal

Heavy metals are elements that are naturally occurring that can be found throughout the earth crust. Nowadays, existing of multiple industrial, domestic, agricultural, medical and technological applications have led to their wide distribution in the environment; raising concerns over their potential effects on human health and the environment. Heavy metal toxicity depends on several factors including the dose, route of exposure, and chemical species, as well as the age, gender, genetics, and nutritional status of exposed individuals (Tchounwou et al., 2010). Regardless of their atomic mass or density, any toxic metal may be called heavy metal. Any heavy metal may be considered as a contaminant if it can cause harmful to human or environmental effect (Singh et al., 2011).

ii. Health Risk Assessment

A process to estimate the nature and probability of adverse health effects in human who may be exposed to chemicals in contaminated environmental media either now or in the future is known as Health Risk Assessment. Human health risk assessment includes 4 basic steps which are planning and scoping process, hazard identification, dose-response assessment, exposure assessment and risk characterization (EPA, 2016).

1.5.2 Operational Definition

i. Water Quality

Physicochemical parameters such as pH, turbidity, and total dissolved solid were measured in-situ. For BOD, APHA 5220 D was used and APHA 5210b for COD.

ii. Heavy Metal

Heavy metals were detected using inductively coupled plasma mass spectrometry.

iii. Health Risk Assessment

Health risk assessment of heavy metal in water is calculated by using USEPA method (2009).

1.6 Objective

1.6.1 General Objective

To assess the level of water quality and heavy metals pollution and its association with health risk of Bertam River, Cameron Highlands.

1.6.2 Specific Objectives

1. To determine the physicochemical properties and the concentration of heavy metals (Zinc, Cadmium, Lead, Chromium, and Copper) in the Bertam River, Cameron Highland.
2. To compare the physicochemical properties and heavy metals concentration with the allowable level according to National Water Quality Standards for Malaysia.
3. To compare the physicochemical properties and heavy metals concentration between the upstream and downstream of the Bertam River.
4. To determine the association between the physicochemical properties and heavy metals of Bertam River, Cameron Highlands
5. To determine the health risk from heavy metals exposure via water consumption.

1.7 Study Hypothesis

1. There is a significant difference between the physicochemical properties and heavy metals concentration with the upstream and downstream of the Bertam River.

2. There is a significant association between the physicochemical properties and heavy metal of Bertam River, Cameron Highlands.

3. There is significant health risk from heavy metals exposure via water consumption.

CHAPTER 2

LITERATURE REVIEW

2.1 Water Quality

As time passes, the quality and the availability of water from the river became deteriorated due to some reasons such as increasing number of population and urbanization. Water quality can be referring as the physical, chemical and biological characteristics of water. To determine the water quality of the river, the interaction of pollution loads from the tributary flowing in should be taken as important things to discover. Besides that, the physical, chemical and biological quality of river water is critically important, because they are linked to every aspect of human wellbeing and sustainable development (UN, 2012).

Water turbidity can be referring as the quantity of solids suspended in the water. These solids may comprise clay, silt, inorganic/organic matter, plankton is proportional and other microscopic organisms (EPA, 2000). Higher turbidity levels means there are pathogen risk factors (Khan et al., 2013), typically associated with higher levels of disease-causing microorganisms such as parasites, viruses and some bacteria. Therefore, monitoring water quality is essential in determining the effect of human activities, the suitability of water for human use and fluxes of sediment and contaminants to the river (Chapman et al., 2006).

As stated by the World Health Organization, 89% of the world population consumes drinking water from improved drinking water sources (WHO, 2013).Piped treated water connections, public standpipes and protected dug well are examples of improved drinking water sources (CDC, 2015).Although the sources of the drinking water had been improved, but this type of sources still can be contaminated by heavy metal from various sources (Guidotti et al., 2015). Meanwhile, heavy metal pollution is an environmental crisis that accompanies rapid economic development in many countries (Souza and Wasserman, 2015). Previous study also stated that heavy metal contamination of treated drinking water is associated with the quality of the water sources, such as river water (Bobaker et al., 2014). There are many types of physical parameters such as pH, turbidity, total dissolved solids, chemical oxygen demand (COD), biological oxygen demand (BOD) used for the evaluation of water quality. Each of the parameters has significant impact on the water quality (Department of Irrigation and Drainage, 2009).

2.1.1 pH

pH is the measurement of the hydrogen-ion concentration in the water. A pH below 7 is acidic and a pH above 7 is basic. pH varies depending on the geology of the river catchment, on river flow, and on wastewater discharges but is generally in the range 6 – 9. It can also be influenced by biological processes, which is carbon dioxide uptake by plants during photosynthesis (EPA, 2005). The pH value is of importance in determining the corrosively of water, but the relationship with a number of other parameters is complex (WHO, 2007).

pH is a measure of the acid strength in the water. The lower the pH, the more acidic the water (Davis et al., 2005). Low pH causes toxic elements and compounds to become available for uptake by aquatic plants and animals (Karthik et al., 2014). Although pH usually has no direct impact on water consumers, it is one of the most important operational water quality parameters. pH may be a problem in the highly industrial regions due to the potential of generating acid rain and runoff (Department of Irrigation and Drainage, 2009) .Careful attention to pH control is necessary at all stages of water treatment to ensure satisfactory water clarification and disinfection (WHO, 2007).

2.1.2 Total Dissolved Solid

Total Dissolved Solids (TDS) is a measure of the amount of dissolved material in the water column. Dissolved material such as sodium, chloride, and magnesium contribute to raise the residue values. High concentrations of TDS limit the suitability of water as a drinking source and irrigation supply (EPA, 2005).

TDS in drinking-water originate from natural sources, sewage, urban run-off, industrial wastewater. TDS also can come from the chemicals used in the water treatment process, and the nature of the piping or hardware used to convey the water such as plumbing (Water Research Center, 2014). The high TDS concentration in the rivers shows the presence of extreme anthropogenic activities along the river course and runoff with high suspended matter (UNESCO, 2001).

2.1.3 Turbidity

Water turbidity is proportional to the quantity of solids suspended in the water. These solids may comprise clay, silt, inorganic or organic matter, plankton and other microscopic organisms (EPA, 2000). Rainfall-generated runoff and sediment suspension within the river contribute to increased suspended sediment loads over a short period of time and leading to elevated turbidity (Goransson et al. 2013).

Also, in general, following a high rainfall event, increased runoff will bring sediments and organic matter which will increase the levels of turbidity and colour in the river (Bertone et al., 2016). High levels of turbidity increase the total available surface area of solids in suspension upon which bacteria can grow. Besides that, high turbidity interferes with the disinfection of drinking water and is aesthetically unpleasant (WHO, 2005).

2.1.4 Biological Oxygen Demand (BOD)

Biochemical Oxygen Demand (BOD) determines the strength of pollutants in terms of oxygen required to stabilize domestic and industrial wastes (Avvannavar and Shrihari, 2007). The BOD value in rivers often increases during periods of heavy rain and high river flows as organic matter is washed in from the land and farmyards (WHO, 2005).

BOD determines the strength of pollutants in terms of oxygen required to stabilize the wastes. It also measures the amount of food for bacteria found in water. The BOD test provides a rough idea of how much biodegradable waste is present in the water (WSDE, 2002). The BOD concentration continuously increases because of natural plant decaying process and other contributors that increase the total nutrient in water bodies such as fertilizer, construction effluent, animal farm, and septic system (Al-Sabahi et al., 2007).

2.1.5 Chemical Oxygen Demand (COD)

The COD test is commonly used to measure the amount of organic and inorganic oxydizable compounds in water (Davis et al., 2005). The increasing of COD indicates that the local pollutants may be contributing incrementally in degrading the quality of the river water (Naubi et al., 2015).

Generally, the lower COD level indicates a low level of pollution, while the high level of COD points out the high level of pollution of water in the study area (Waziri et al., 2010). Moreover, a wide usage of chemical and organic fertilizer and discharge of sewage affect COD level, while the high COD shows a deterioration of the water quality is attributed to the discharge of municipal effluent (Eisakhani et al., 2009).

COD level are related to anthropogenic pollution sources and are suspected to come from point sources pollution such as sewage treatment plants and industrial effluents (Juahir et al., 2010).

2.2 National Water Quality Standards for Malaysia.

The levels Permissible levels of physicochemical and heavy metals in the Bertam River, Cameron Highlands can be compared to National Water Quality Standards for Malaysia. The National Water Quality Standards describes the quality parameters set for drinking water in Malaysia.

Table 1: Permissible levels of physicochemical and heavy metals addressed in National Water Quality Standards for Malaysia.

Element	Permissible Level
Turbidity	5 NTU
pH	6.5-8.5
Total Dissolved Solid (TDS)	1000 mg/L
Chemical Oxygen Demand (COD)	1.0 mg/L
Biological Oxygen Demand (BOD)	10.0 mg/L
Cadmium (Cd)	0.01 mg/L
Copper (Cu)	0.02 mg/L
Zinc (Zn)	5.0 mg/L
Chromium (Cr)	0.05 mg/L
Lead (Pb)	0.01 mg/L*

* National Drinking Water Quality Standards

2.3 Sources of Water Pollution

2.3.1 Domestic sources

Domestic waste discharge continue to pollute the rivers, it can be either directly from the surface runoff or indirectly through drains and river tributaries. On the other hand, the negative impact of anthropogenic activities on the river systems is cumulative in nature. They are caused by processes and activities which accumulate over time and space (Ren et al., 2003)

There are seven causes of main water problems in Bertam River included the land use change either legal or illegal development, uncontrolled river water abstraction in upstream, poor solid waste management, low awareness of local community, unplanned development, and inefficient administration (Kok Weng et al., 2011).

Human activities, resulting from urban areas, and agricultural activities, resulting from vegetation area, are the main sources of water pollution through the discharge of domestic and agricultural wastewater into the river. Agricultural canals and drains are distributed in the cultivated area which boosts the river contamination(El-Zeiny and El-Kafrawy, 2016).

Leaching of metals from water distribution system (WDS) can contaminate drinking water (Alabdula'aly and Khan, 2009). Amirah et al. (2016) reported that visible concentration of Cu, Pb and Cd were found in the certain river in Pahang. Besides that, varying levels heavy metals contamination was discerned in the Semenyih River (Gasim et al.,2000).

2.3.2 Agriculture sources

River water quality globally has been effected by anthropogenic activities, in many cases in ways that still have to be fully quantified (Meybeck, 2005). While these impacts are increasingly acknowledged, our ability to understand the magnitude of anthropogenic forcing is constrained by the limited availability of long-term water quality data-sets, which are essential in understanding system behaviour (Burt et al., 2014).

Besides that, agricultural activities, tourism and urban development in an area of Cameron Highlands that causing an aggressively of land use change also had mentioned in the previous study (Hashim et al., 2006) .Furthermore, after passing through the settlement and agricultural areas, Bertam River also was heavily contaminated with sedimentation problems .The climate of Cameron Highlands had been affected because of active deforestation in recent years (Jaafar et al., 2010). Previous study by Leong et al., (2007) mentioned that agriculture, urban and industrial activities coupled with high population growth have caused deterioration in the river water quality.

2.4 Heavy Metals Contamination

2.4.1 Zinc

Zinc is a one of the most well-known components in the Earth's crust. Most zinc are found naturally in the environment is in the form of zinc sulfide. Zinc compounds are generally utilized as a part of industry. Zinc sulfide and zinc oxide are used to make white paints, ceramics, and other items. Zinc enters the air, water, and soil as a consequence of both regular procedures and human activities. Generally zinc enters the environment as the result of mining, purifying of zinc, lead, and cadmium ores, steel production, coal burning, and burning of wastes. These activities can increase zinc levels in the atmosphere. Waste streams from zinc and other metal manufacturing and zinc chemical industries, domestic waste water, and run-off from soil containing zinc can discharge zinc into waterways (ATSDR, 2006).Besides that, the agricultural sector also contributes to contamination of heavy metal in river (Shazili et al., 2006)

The recommended dietary allowance (RDA) for zinc is 11 mg/day for men and 8 mg/day for women (Trumbo P. et al., 2001). Some essential metals like Cu, Mn, and Zn are required for normal body growth but excess amount of these metals could also be harmful (Ouyang et al., 2002). Excessive intake of zinc can cause fever, coughing, stomach pain, fatigue, and many other problems (Haase H. et al., 2008). Ingestion of water containing certain amount of heavy metals may cause health problems in human including shortness of breath (Kavcar et al., 2009).

2.4.2 Cadmium

Cadmium is a widespread metallic element occurring in the environment naturally (e.g., volcanic activity, weathering of Cd-containing rocks, and sea spray), and as a pollutant emanating from industrial (e.g., batteries, coatings, and plastic stabilizers), agricultural (e.g., contamination of phosphate fertilizers), and other sources (e.g., release from motor vehicle fuel combustion and tire wear) (Agency for Toxic Substances and Disease Registry, 2011). Cadmium is known as one of the most toxic elements in the environment, with a wide range of organ toxicity and long elimination half-life (Patrick, 2003).

The third most frequently reported heavy metal in drinking water is Cd, and it has been pointed as a public health concern (ATSDR, 2015; USEPA, 2015). Cd-contaminated drinking water was linked to chronic renal failure (Bawaskar et al., 2010). reported kidney failure due to long-term exposure to Cd. Chronic exposure to Cd could lead to anemia, anosmia (loss of sense of smell), cardiovascular diseases, renal problems, osteoporosis, and hypertension (ATSDR, 2015). Cd can bind with cysteine, glutamate, histidine, and aspartate ligands and can cause iron deficiency (Irfan et al., 2013). It can cause both acute and chronic intoxications (Chakraborty et al., 2013).

Ingesting high levels of cadmium will cause stomach ache which leads to vomit and diarrhea. Chronic exposure to cadmium causes build up in the kidney and increase the probability to get kidney disease (Martin and Griswold, 2009). Laboratory and animal studies shows a strong evidence for carcinogenic effects of cadmium including mutations in cultured cells, strand breaks in DNA and chromosomal aberrations (Filipic and Hei, 2004). Previous study also stated that high exposure to can lead to prostate cancer (Achanzar et al., 2001). Henson and Chedrese (2004) reported the association of Cd exposure during pregnancy with premature birth and reduced birth weights.

2.4.3 Chromium

In environmental samples, chromium occurs most frequently in two oxidation states, trivalent chromium (chromium-3, Cr (III), Cr3+) and hexavalent chromium (chromium-6, Cr (VI), Cr6+). The toxicity of Cr depends primarily on its chemical form; Cr(III) compounds are much less toxic than those of Cr(VI) (Langard et al. 2014).

The International Agency for Research on Cancer (IARC) has classified Cr(VI) compounds as carcinogenic to humans (Group 1) (IARC, 2012). Chromium can enter waters from both anthropogenic and natural sources (Catalani et al., 2015).Chromium can cause irritation to the nose lining and also can cause breathing problem (Martin and Griswold, 2009).

2.4.4 Lead

Today, the main routes of lead exposure for the general adult population are from ingestion of food and drinking water. For infants and children, the primary routes of exposure are food, drinking water, and the incidental ingestion of house dust, lead-based paint, soil, and consumer products (Health Canada, 2013).

Few heavy metals, such as lead and mercury, can also enter the atmosphere due to traffic pollution and industrial activities, which can be deposited in soils around the reservoir and then enter the water along with the surface runoff (Wang et al., 2015)

Children and pregnant women are particularly susceptible to lead poisoning. The digestive system of children absorb 50% of the lead ingest (National Referral Centre, 2009). Lead can have serious consequences for the health of children. At high levels of exposure, lead attacks the brain and central nervous system to cause coma, convulsions and even death (WHO, 2016).

2.4.5 Copper

Copper is a metal that occurs naturally in rock, soil, plants, animals, and water. The level of copper in surface and groundwater is generally very low. High levels of copper may get into the environment through mining, farming, manufacturing operations, and municipal or industrial wastewater releases into rivers and lakes (CDC, 2015). Cu is toxic at high levels. An overload of this metal easily leads to Fenton-type redox reactions, resulting in oxidative cell damage and cell death (Turlund et al., 2005).

2.5 Effect of Water Quality and Heavy Metals to Human Health

Metal elements constitute an environmental threat by creating serious human health hazards and affecting ecological food chains (Xuelu and Chen-Tung Arthur, 2012). Presence of heavy metal will adversely effects the drinking and irrigation quality of water (Krishna et al., 2009).Ingestion of water containing certain amount of heavy metals can cause health problems in human, including shortness of breath and various types of cancer (Kavcar et al. 2009).

There are certain types of heavy metals that essential in human body for normal body growth and function such as Cu, Mn, Zn, but the excess amount of these metals could be harmful and their accumulation in the body can cause serious disease (Khan S. et al., 2013). The adverse effect of these heavy metal are depends upon the heavy metal species either toxic, neurotoxic, carcinogenic or mutagenic (Sharma et al., 2008).

Despite the fact that the common pollutants in industrial wastewater led to increased health risks, the health effects varied among the elements found in water pollution. Contrast to other elements, heavy metals had greater effects on mental health but not on physical health instantly. One possible clarification for this difference may be that although the negative impsacts of heavy metal are well known, heavy metal contaminants may not instantly negative influence physical health until heavy metal accumulates in the human body to a threshold and has long-term effects on physical health, while non-metallic pollutants may be gradually detoxified in vivo (Cheng,2003).

Spickett et el., (2012) mentioned that, HRA is crucial to understand the potential health risk from the heavy metal exposure to humans. Information from HRA will be a very important information for decision makers to set up policies or regulations to protect population's health (Sobus et al., 2011).

Researchers have reported there are connections between water pollution and acute water-borne diseases which include hepatitis, cholera, dysentery, cryptosporidiosis, giardiasis, diarrhea and typhoid (Cutler and Miller, 2005). Raikwar et al. (2008) found that heavy metals such as Cd, and Pb pose a number of hazards to humans. These metals are also potent carcinogenic and mutagenic. Heavy metal toxicity can result in damaged or reduced mental and central nervous system function, lower energy levels, and damage to blood composition, lungs, kidneys, liver, and other vital organs. Long-term exposure may result in slowly progressing physical, muscular, and

Alzheimer's disease, Parkinson's disease, muscular dystrophy, and multiple sclerosis. Allergies are not uncommon and repeated long-term contact with some metals or their compounds may even cause cancer.

2.6 Health Risk Assessment

There is a lot of previous study that compared the heavy metal contamination in drinking water with local and WHO standards and the result showed the concentration of the heavy metals from Turkey, Pakistan, Jordan, Germany and Malaysia are below permissible limits (Kavcar et al., 2006).However, by comparing the concentration of heavy metals in drinking water with the standard alone are not enough to indicate the health risks caused by heavy metal exposure through drinking water .The information on the risk of heavy metal exposure through drinking water for the population can be obtained after conducting health risk assessment (HRA) (Razak et al., 2015).

Environmental Protection Agency (EPA) stated that, the HRA process involves calculation of the hazard quotient (HQ) and the lifetime cancer risk (LCR) using variables such as heavy metal concentration, ingestion rate, body weight, exposure duration and slope factor (Muhammad et al., 2015).If the result of HQ is less than 1 ,it indicates no non-carcinogenic health risk to humans. The acceptable ranges for LCR are from 1 in 10000 to 1in 1 million (Razak et al., 2015).Exposure to heavy metals can lead to both non-carcinogenic and carcinogenic effects to the population (Muhammad et al., 2015).

Presence of heavy metal will adversely effects the drinking and irrigation quality of water (Krishna et al., 2009).Ingestion of water containing certain amount of heavy metals can cause health problems in human, including shortness of breath and various types of cancer (Kavcar et al.,2009).There are certain types of heavy metals that essential in human body for normal body growth and function such as Cu, Mn, Zn , but the excess amount of these metals could be harmful and their accumulation in the body can cause serious disease (Khan et al., 2010). The adverse effect of these heavy metal are depends upon the heavy metal species toxic, neurotoxic, carcinogenic or mutagenic (Sharma et al., 2008).

Spickett et el., (2012) mentioned that, HRA is crucial to understand the potential health risk from the heavy metal exposure to humans. Information from HRA will be a very important information for decision makers to set up policies or regulations to protect population's health (Sobus et al., 2011).

CHAPTER 3

METHODOLOGY

3.1 Study Design

A cross-sectional design was conducted in this research. The physicochemical properties and also the level of heavy metal were measured from the water in Sungai Bertam, Cameron Highlands. The health risk from heavy metals exposure via water among population who lived near Bertam River, Cameron Highlands were measured by using secondary data.

3.2 Background of Study Area

This research was conducted at the Bertam River which is located in the area of Cameron Highlands in the state of Pahang. Cameron Highlands is well known for its agricultural and tourism activities. Cameron Highlands also one of the largest hill resort in Malaysia. The cold and temperate weather makes the area of Cameron Highlands is the most suitable area for many agricultural products .The area of Cameron Highlands is drained by eight rivers and 123 tributaries. There are three major rivers in Cameron Highlands that are known as Bertam River, Lemoi River and Telom River. Cameron.Highlands plays a vital role in supplying water for drinking water, irrigation and hydroelectricity generation. The Bertam River which is the study area as shown in the figure 2, has total area about 293.7 km^2 and is drained by complicated river network influenced by hilly and undulating terrain system. Bertam river act as the main river flowing from Gunung Brinchang at the upstream, through Brinchang town, Tanah Rata, Habu and into Ringlet reservoir.

There are five main tributaries in Upper Bertam namely Sungai Burung , Sungai Ruil ,Sungai Jasar, Sungai Uluh and Sungai Batu Pipih. Ulu Sg. Bertam originates from the eastern face of Gunung Brinchang and later, as Sg. Bertam, flows through Brinchang, Cameron Highlands' Nine, Tanah Rata,Robinson's Falls and through Habu and becomes part of the Sultan Abu Bakar reservoir.

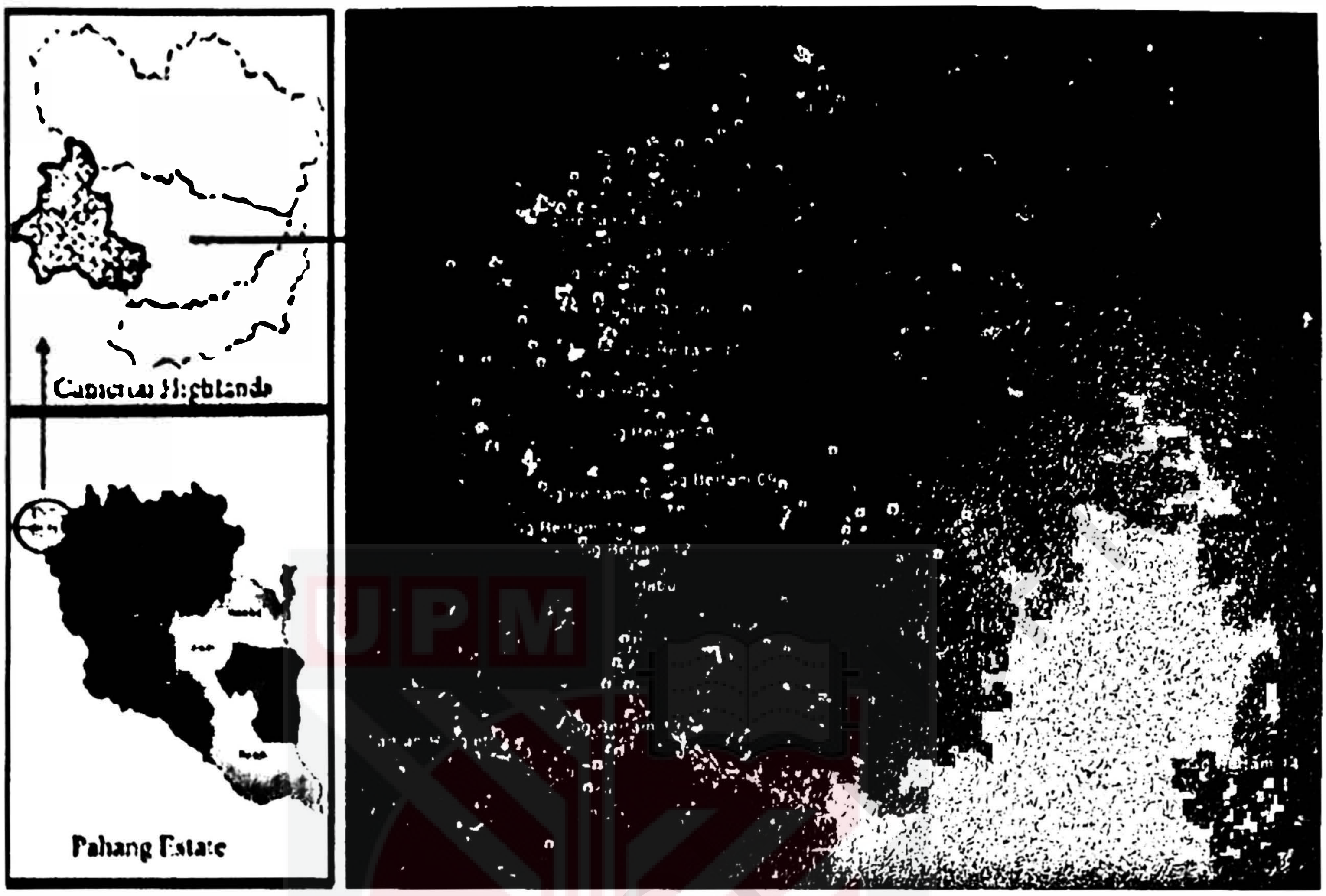

Figure 3.1: Location of Bertam River, Cameron Highlands, Pahang.

3.3 Sampling Method

The sampling method of this research was purposive sampling .Purposive sampling was used to select the sampling point in the Bertam River, Cameron Highlands. Water sample were collected at 15 cm depth from the surface of the river water following the grab method. Sampling was collected using HDPE bottles for COD test and amber glass bottles for BOD test. For heavy metal, sample was collected were sample using HDPE bottles and acidified immediately with 3 ml nitric acid (69%) before the HDPE bottles sealed. All samples were stored in cooler box filled with ice packs to keep temperature below 4°c before transferring to the laboratory. Physicochemical parameters of water quality were measured in situ for pH, salinity, total dissolved solid, and turbidity using portable YSI (model 6600-M) multisensory probe. The probes of the YSI model 6600-M were calibrated in the laboratory before the sampling program. APHA 3120 B standard procedures were followed during sampling, sample transportation and preservation (Figure 3.2).

Figure 3.2: During water sampling at Bertam River, Cameron Highlands.

3.4 Sampling Collection

Sampling collection was conducted at the 14 selected stations. Criteria for selection of sampling points were based on the location that have an important roles as a location for potential point and non-point of pollution sources .The description of sampling locations in Bertam Catchment area are as in Table 3.1.

Table 3.1: The description of sampling locations in Bertam Catchment area

Catchment	Station	Latitude	Longitude	Elevation,m	Station description and selection criteria
Upper Bertam	SB-1	04.50556^0	101.38768^0	1612	Sloppy mountainous and forest area. Source area of the river.
	SB-2	04.48974^0	101.38715^0	1474	Around tea plantation and agriculture area.
	SB-3	04.48701^0	101.38451^0	1449	Adjacent to Taman Sedia residential area and farming area.
	SB-4	04.48152^0	101.38032^0	1440	Near to Iris House and residential area.
	SB-5	04.47459^0	101.38402^0	1416	Recreational area.
	SB-6	04.47123^0	101.38114^0	1398	Farming and residential area.
	SB-7	04.46589^0	101.38569^0	1386	Residential area.
	SB-8	04.45404^0	101.39114^0	1117	Around tea plantation and residential area.
	SB-9	04.45127^0	101.39127^0	1102	Agriculture and residential area
Lower Bertam	SB-10	04.44738^0	101.39148^0	1084	Tea and farming area.
	SB-11	04.44272^0	101.38789^0	1056	Around tea plantation and agriculture area.
	SB-12	04.43840^0	101.38883^0	1044	Around tea plantation and village area.
	SB-13	04.41730^0	101.39764^0	1026	Around commercial area
	SB-14	04.41633^0	101.46473^0	861	Near to intensive farming and residential area.

3.5 Sample Analysis

COD measurement was analyzed using reactor digestion and colorimetric determination method (APHA, 2012). For BOD, it was analyzed by using 5 days incubator method where the samples were kept in incubator at 20^0C temperature for 5 days (APHA, 2012). Heavy metals concentration (Cd, Cr, Pb, Zn and Al) in the river were analyzed using inductively coupled plasma mass spectrometry. (Table 3.2).

Table 3.2: Limit of detection of measured heavy metals by inductively coupled plasma mass spectrometry.

Heavy Metal	LOD (µg/L)
Cu	0.005
Cd	0.005
Cr	0.01
Zn	0.01
Pb	0.01

3.6 Quality Assurance and Quality Control

1. All the physicochemical properties such as turbidity, pH, and total dissolved solid were measured in triplicate at each point by using portable YSI (Rasul et al. 2015)

2. To maintain the quality of samples, the samples were kept in the ice box with temperature between 1^{o}c to 4 ^{o}c.

3. The apparatus for measurement was calibrated before analyzing sampling (Rasul et al. 2015).

3.7 Health Risk Assessment

Both equations for non-carcinogenic and carcinogenic health risk are adapted from USEPA, 2009. The health risk assessment was applied to adult and children via water consumption as the route of exposure.

3.7.1 Non-carcinogenic health risk

According to the US Environmental Protection Agency, the intake of heavy metals such as Zinc, Cadmium and Copper can have non-carcinogenic effects to humans (US EPA, 2011).Average Daily Dose (ADD) is used in the calculation of non-carcinogenic risk (Table 3.3).

ADD was calculated as follows:

$$ADD = \frac{C \times IR \times EF \times ED}{BW \times AT}$$

Table 3.3: The parameter used in health risk calculation

Variable		Value	Unit	Source
C = Average concentration of heavy metal		Depend on results of this research	mg/kg	Based on the results of this research
IR = Ingestion rate	Adult	1.9961	l/day	Ab Razak N.H. et al., (2016)
	Children	0.0002	kg/day	US EPA (2002)
EF = Exposure frequency	Adult	365	days/year	US EPA (2011)
	Children	350		
ED = Exposure duration	Adult	74	Years	Malaysian Department of Statistics (2010)
	Children	6		Grzetic&Ghariani (2008)
BW = Body weight	Adult	70	Kg	Malaysian Department of Statistics(2010)
	Children	15		USEPA(2002)
AT = Average period of exposure	Adult	27010	Days	USEPA (2011)
	Children	2190		

Note: USEPA= United State Environmental Protection Agency

For non-carcinogenic risk, HQ>1 indicates significant risk while HQ<1 indicates no significant risk. HQ was calculated as follow:

$$HQ = \frac{ADD}{RfD}$$

Oral reference dose of heavy metal (RfD) used in this study are shown in Table3.4.

Table 3.4: Oral reference dose of heavy metal (RfD) for non-carcinogenic risk

Heavy Metal	RfD (mg/kg/day)	Source
Cu	4.0×10^{-2}	IRIS (2012)
Cd	5.0×10^{-4}	IRIS (2012)
Zn	3.0×10^{-1}	IRIS (2012)

IRIS= Integrated Risk Information System (2012)
US EPA= United State Environmental Protection Agency (2011)

3.7.2 Carcinogenic health risk

According to the US Environmental Protection Agency, the intake of heavy metals such as Lead and Chromium can have carcinogenic effects to humans (US EPA, 2011. Lifetime Average Daily Dose (ADD) is used in the calculation of non-carcinogenic risk.

LADD was calculated as follows:

$$LADD = \frac{C \times IR \times EF \times ED}{BW \times AT}$$

Table 3.5: The parameter used in health risk calculation

Variable		Value	Unit	Source
C = Average concentration of heavy metal		Depend on results of this research	mg/kg	Based on the results of this research
IR = Ingestion rate	Adult	1.9961	l/day	Ab Razak N.H. et al. (2016)
	Children	0.0002	kg/day	US EPA (2002)
EF = Exposure frequency	Adult	365	days/year	US EPA (2011)
	Children	350		
ED = Exposure duration	Adult	74	Years	Malaysian Department of Statistics (2010)
	Children	6		US EPA (2002)
BW = Body weight	Adult	70	Kg	Malaysian Department of Statistics (2010)
	Children	15		US EPA (2002)
AT = Average period of exposure	365 × ED child or adult		Days	US EPA (2011)

Note: US EPA= United State Environmental Protection Agency (2011)

Risk between 1×10^{-6} and 1×10^{-4} is considered as acceptable risk. There is a significant risk if higher than 1×10^{-4}. The carcinogenic risk was calculated as follow:

$$Risk = LADD \times CSF$$

Cancer Slope Factor (CSF) used in this study are shown in Table 3.6.

Table 3.6: Cancer Slope Factor (CSF) for carcinogenic risk

Heavy Metal	CSF (mg/kg/day)	Source
Cr	5.0×10^{-1}	US DOE (2011)
Pb	8.5×10^{-3}	US DOE (2011)

US DOE= United State Department of Environment (2011)

CHAPTER 4

RESULT

4.1 Physicochemical Properties of the Bertam River in Cameron Highland.

Table 4.1 highlights the water quality parameter in general and Table 4.2 provide the overview in the 14 sampling points in Bertam River area. The pH level of Bertam River during the study sampling ranged from 6.61 to 7.47 with a mean of 6.90 and standard deviation of 0.19. For total dissolved solid (TDS), the result was in a range of 0.03 to 0.08 g/L with a mean of 0.03 g/L and standard deviation of $\pm$0.02 g/L. The turbidity of the Bertam River was in a range of 3.96 NTU to 587.45 NTU with a mean of 234.74 NTU and the standard deviation was $\pm$257.28 NTU. The BOD concentration was in a range of 0.6 to 18.8 mg/L. The mean and standard deviation for BOD was 2.94 +4.82 mg/L. For COD, the result shows the concentration of COD in a range of 7.03 to 33.18 mg/L with mean of 17.23 mg/L and the standard deviation was $\pm$7.66 mg/L.

Table 4.1: Statistical summary of physical parameters for water samples in the Bertam River area (n=14).

	pH	TDS, g/L	COD, mg/L	BOD, mg/L	Turbidity, NTU
Minimum	6.62	0.01	7.03	0.00	3.96
Maximum	7.47	0.08	33.18	18.80	587.45
Mean±SD	6.90±0.19	0.03±0.02	17.23±7.66	2.94±4.82	234.74±257.28

Table 4.2: Statistical summary of physical parameters for water samples in the 14 sampling points in Bertam River area (n=14).

Catchment	Station	pH	TDS, g/L	Turbidity, NTU	COD, mg/L	BOD, mg/L
Upper Bertam	SB-1	6.90±0.02	0.01±0.00	3.96±0.18	7.03	BDL
	SB-2	6.96±0.01	0.062±0.038	13.49±0.56	33.18	18.8
	SB-3	6.83±0.00	0.056±0.00	23.97±0.15	16.24	5.1
	SB-4	6.82±0.00	0.053±0.00	45.70± 1.69	14.48	3.6
	SB-5	6.90±0.06	0.049±0.00	15.55±1.40	12.95	2.8
	SB-6	6.80±0.01	0.047±0.00	20.81±0.61	11.75	0.8
	SB-7	6.90±0.07	0.050±0.00	25.57±1.32	15.09	3.9
	SB-8	6.62±0.01	0.034±0.00	537.17±0.47	19.83	0.6
	SB-9	6.99±0.01	0.034±0.00	537.37±0.84	20.72	1.1
Lower Bertam	SB-10	6.79±0.02	0.0267±0.007	527.55±18.06	21.24	1.1
	SB-11	6.79±0.01	0.037±0.00	523.14±0.93	29.64	1.1
	SB-12	6.76±0.01	0.040±0.00	389.63±1.98	21.23	0.8
	SB-13	7.01±0.01	0.025±0.00	34.71±0.16	9.35	1.4
	SB-14	7.47±0.01	0.080±0.00	587.45±108.29	8.52	BDL

Note: BDL-Below Detection Limit

4.2 Concentration of Heavy Metals (Zinc, Cadmium, Lead, Chromium, and Copper), in Bertam River, Cameron Highlands.

The concentration of heavy metals (Cd, Cr, Cu, Pb and Zn) in water samples collected from the 14 sampling points along the Bertam River is summarized in Table 4.3 and 4.4. The concentration of the cadmium is below detected limit in all sampling points. For chromium concentration, there were six sampling point that shows the concentration of the chromium that ranged between 0.014 to 0.01 mg/L with a mean of 0.006 mg/L and standard deviation of $\pm$0.007 mg/L. Twelve (12) sampling stations shows the concentration of the copper between 0.005 to 0.014 mg/L. The mean and standard deviation for copper was 0.009$\pm$0.005 mg/L. For lead, the concentration ranged from 0.017 to 0.026 mg/L with a mean and standard deviation of 0.009$\pm$0.011 mg/L. All fourteen sampling station shows the concentration of zinc that ranged from 0.03 to 0.11 mg/L with a mean of 0.041 mg/L and standard deviation of $\pm$0.027 mg/L.

Table 4.3: Concentration of heavy metal in the Bertam River area. All heavy metals are in mg/L, (n=14).

	Cadmium	Chromium	Copper	Lead	Zinc
Minimum	BDL	BDL	BDL	BDL	BDL
Maximum	BDL	0.016	0.016	0.026	0.110
Mean±SD	BDL	0.006±0.007	0.009±0.005	0.009±0.011	0.041±0.027

BDL-Below Detection Limit

Table 4.4: Concentration of heavy metals in 14 water sampling station along the Bertam All heavy metals are in mg/L (n=14).

Catchment	Station	Cadmium	Chromium	Copper	Lead	Zinc
Upper Bertam	SB-1	BDL	BDL	0.005	BDL	0.03
	SB-2	BDL	BDL	BDL	BDL	0.03
	SB-3	BDL	BDL	0.007	BDL	0.02
	SB-4	BDL	BDL	0.009	BDL	0.02
	SB-5	BDL	BDL	0.013	BDL	0.02
	SB-6	BDL	BDL	BDL	BDL	0.02
	SB-7	BDL	BDL	0.005	BDL	0.02
	SB-8	BDL	0.015	0.016	0.026	0.11
	SB-9	BDL	0.014	0.012	0.025	0.06
Lower Bertam	SB-10	BDL	0.014	0.012	0.022	0.06
	SB-11	BDL	0.016	0.014	0.022	0.06
	SB-12	BDL	0.01	0.014	0.017	0.05
	SB-13	BDL	BDL	0.013	BDL	0.02
	SB-14	BDL	0.015	0.011	0.02	0.06

Note: BDL-Below Detection Limit,

4.3 Physicochemical properties and concentration of heavy metals in water samples comparable to Malaysian National Water Quality Standard (NWQS).

All parameters are within the NWQS except for turbidity and Pb concentration (Table 4.5). High turbidity value was recorded in the Sg. Bertam water samples where the standard was 5.0 NTU and the mean and SD of the water samples were 234.74 + 257.28 NTU. Thirteen of the samples (13) exceed the standard value. Lead concentration exceeds the standard value (0.01 mg/L) in 6 sampling stations in this study. Based on the table 4.5, it shows low significant difference between the zinc concentrations in Bertam River compared with the Malaysian Drinking Water Standard.

Table 4.5: The comparison of physicochemical properties with the Malaysian National Drinking Water Quality Standard (NDWQS).

Variable	(n=14) Mean $\pm$ SD	NWQS	No. of sample exceed NWQS
pH	6.895 $\pm$ 0.194	6.5-8.5	0
TDS, g/L	0.033 $\pm$ 0.019	1.0	0
Turbidity, NTU	234.74 $\pm$ 257.28	5	13
Chromium concentration (mg/L)	0.006 $\pm$ 0.007	0.05	0
Copper concentration (mg/L)	0.009 $\pm$ 0.005	0.02	0
Lead concentration (mg/L)	0.009 $\pm$ 0.011	0.01	6
Zinc concentration (mg/L)	0.041 $\pm$ 0.027	5.0	0

* Significant at the p value ≤ 0.05 (2-tailed)

4.4 The comparison of physicochemical properties and concentration of heavy metals in water samples between upstream and downstream of Bertam River.

Parametric test (One-Way ANOVA) was used to analyze the comparison of the physicochemical properties and concentration of heavy metals between upstream and downstream of Bertam River (Table 4.6). In this study, 9 sampling stations (SB 1 to SB 9) were classified as upper Bertam while 5 sampling stations (SB 10 to SB 14) were classified as the lower Bertam. The classification was made based on the elevation model of the river (NAHRIM, 2017). Based on the table, it shows that there are significance difference between upper and lower of the Bertam River for turbidity.

Table 4.6: Comparison of the physicochemical properties and concentration of heavy metals between upstream and downstream of Bertam River (n=14)

Variable	Mean (SD)		F-statistics (df)	p-value*
	Upper (n=9)	Lower (n=5)		
pH	6.86 (0.11)	6.96 (0.30)	1.005 (1,12)	0.336
TDS	0.03 (0.01)	0.04 (0.03)	1.728 (1,12)	0.213
COD	16.81 (7.40)	18.00 (8.94)	0.072 (1,12)	0.793
BOD	4.08 (0.88)	5.79 (0.54)	1.465 (1,12)	0.249
Turbidity	135.99 (227.87)	412.50 (223.23)	4.797 (1,12)	0.049*
Chromium	0.00322 (0.0064)	0.0110 (0.0066)	4.671 (1,12)	0.052
Copper	0.0070 (0.0056)	0.0128 (0.0013)	4.304 (1,12)	0.060
Lead	0.0057 (0.0112)	0.0162 (0.0093)	3.154 (1,12)	0.101
Zinc	0.0368 (0.0306)	0.0490 (0.0197)	0.638 (1,12)	0.440
Cadmium	BDL	BDL	BDL	BDL

BDL-Below Detection Limit

* p-value significant at 0.05 level

4.5 Association between the physicochemical properties and heavy metals of Bertam River, Cameron Highland

Parametric test (Correlation test) was used to analyze the association between the physicochemical properties and heavy metals of Bertam River, Cameron Highland (Table 12). Findings show turbidity was positively correlated with all the heavy metals. Cu was positively correlation with Cr (r=0.648). In addition, Cr has low correlation with pH (r=0.075). Findings also shows strong correlation between Pb with Cr (r=0.989), Cu (r=0.660) .This results indicates a significant influence of one heavy metals to another and suggests the possibility of the metals coming from the same source.

Table 4.7: Association between the physicochemical properties and heavy metals in Bertam River, Cameron Highland (n=14).

Coefficient Correlation, r	pH	TDS	COD	BOD	Turbidity	Cr	Cu	Pb	Zn
pH	1								
TDS	0.532	1							
COD	-0.353	-0.367	1						
BOD	0.017	-0.018	0.574*	1					
Turbidity	0.012	-0.198	0.306	-0.404	1				
Cr	0.075	-0.230	-0.396	-0.396	0.996*	1			
Cu	-0.079	-0.096	0.027*	-0.554	0.649*	0.648*	1		
Pb	-0.004	-0.288	-0.393	-0.393	0.987*	0.989*	0.660*	1	
Zn	-0.128	-0.353	-0.357	-0.249	0.860*	0.873*	0.589	0.897	1

* p-value significant at 0.001 level (2-tailed)

a Pearson correlation

4.6 Health risk from heavy metals exposure via water consumption

The carcinogenic and non-carcinogenic health risk due to the exposure to selected heavy metals was estimated using Lifetime Cancer Risk (LCR) and Hazard Quotient for children and adult in this study were highlighted in Table 4.8 and Table 4.9. According to the Risk Assessment Information System Database (2013), Cd, Cr and Pb are known to be human carcinogenic whereas other elements in this study (Zn and Cu) are known as non-carcinogenic to human.

Levels of 10^{-6} to 10^{-4} are given as a range of "generally acceptable risk" for LCR (Kelly, 1991). The Bertam river catchment, the study area, has a total area of about 293.7 km2 and is drained by a complicated river network influenced by hilly and undulating terrain system. Bertam is the main river flowing from Gunung Brinchang at the upstream, through Brinchang town, Tanah Rata, Habu and into the Ringlet reservoir. Bertam River then flows to Telom River about 24 km downstream of reservoir. The main tributaries in Upper Bertam namely Sungai Burung, Sungai Ruil, Sungai Jasar, Sungai Uluh and Sungai Batu Pipih joint with the main course of Upper Bertam River at different locations before flowing into Ringlet reservoir.

In this study, heavy metal concentration in the Bertam River did posed within acceptable range of carcinogenic risks to children's and adult's health. The non-carcinogenic elements in this study also within an acceptable limit to children and adult as the hazard quotient less than 1.

Table 4.8: Non-carcinogenic hazard quotient and carcinogenic lifetime risk for adult due to exposure to heavy metal

Heavy Metal	Minimum Concentration (mg/kg)	Maximum Concentration (mg/kg)	Mean Concentration ± SD (mg/kg)	LADD (mg/kg-day)	ADD (mg/kg-day)	Carcinogenic Risk	Hazard Quotient (HQ)
Zn	0.00	0.110	0.006+0.007	-	-	0.0013	0.004
Cu	0.00	0.016	0.009+0.011	-	-	0.0003	0.007
Pb	0.00	0.026	0.009+0.005	0.0085	$2.54x10^{-6}$	-	-
Cr	0.00	0.016	0.041+0.027	0.500	$9.5x10^{-5}$	-	-

Body Weight-63 kg (Malaysian Department of Statistics, 2010)
Ingestion Rate-1.9961 l /day (Ab Razak N.H. et al. 2015)

Table 4.9: Non-carcinogenic hazard quotient and carcinogenic lifetime risk for children due to exposure to heavy metal

Heavy Metal	Minimum Concentration (mg/kg)	Maximum Concentration (mg/kg)	Mean Concentration ± SD (mg/kg)	LADD (mg/kg-day)	ADD (mg/kg-day)	Carcinogenic Risk	Hazard Quotient (HQ)
Zn	0.00	0.110	0.006+0.007	-	-	$2.99 x10^{-6}$	$1.20 x10^{-7}$
Cu	0.00	0.016	0.009+0.011	-	-	$1.75 x10^{-6}$	5.26
Pb	0.00	0.026	0.009+0.005	$1.03 x10^{-8}$	$8.78x10^{-11}$	-	-
Cr	0.00	0.016	0.041+0.027	$6.57x10^{-9}$	$3.29x10^{-9}$	-	-

Body Weight-15 kg (US EPA, 2002)
Ingestion Rate-0.0002 kg/day (US EPA, 2002)

CHAPTER 5

DISCUSSION

5.1 Physicochemical Properties of the Bertam River in Cameron Highland.

The pH of the water is considered as one of the important water quality parameters in the aquatic system and a high range pH shows that the drinking water has a bitter taste (Khan et al. 2013). The pH level indicate how acidic the water it is (USEPA, 2007). The lower the number, the more acidic the water is. The released hydrogen ions decrease the pH of water (Fondriest, 2016). In this study, the lowest pH is from SB-8, showing that SB-8 has the most acidic river water compared to the other sampling stations. This possibility related to the man activities, sewage and chemical effluent from the industrial nearby which increased the microbial activities (Azrina, 2002).

There are many factors that can lower the pH of the water. Firstly, the amount of organic material within a body of water, when this material decomposes carbon dioxide is released. The carbon dioxide combines with water to form carbonic acid. Although this is a weak acid, large amounts of it will lower the pH (Water Research Center, 2014). SB-13 has the most neutral river water. For total dissolved solid (TDS), the highest TDS value is at the last sampling point which is SB-14. This may indicate there were influenced by the major point sources such as sewage and agricultural run-off (WHO, 2003).

However, according to the National Drinking Water Quality Standard (NWQS), the TDS value for all sampling points is still acceptable. According to Carle et. al (2005), the increasing value of TDS will decreasing the water quality of the river. Turbidity can be defined as a decrease in the transparency of a solution due to the presence of coloured suspended and dissolved substances. In this study, for turbidity, only one sampling point shows the value within the acceptable value limit .High turbidity in river water is due to land slide and erosion (Dadson et al., 2003). In general, high turbidity was often as a result after high rain fall due to silt, clay and suspended solids by interaction of rainfall, upstream erosion and sediment (Lee et al., 2016). The excess amount of suspended solid in water that resulting to high turbidity can also be an indicator of land erosion in the river catchment (Naubi et al., 2015).

Besides that, the highest level of BOD in this study was at the SB-2, if compared to the National Water Quality Standards for Malaysia, the level of BOD for this sampling point was categorized under class 4. BOD is an indicator for the amount of the biodegradable organic substances. BOD also accounts the oxygen that is required in organic matter decomposition (Amadi et al., 2010). BOD value will rise when there is more organic matter such as leaves, wood, wastewater or urban storm water runoff took place at the river water (Gandaseca et al., 2011).

Besides that, the excessive quantities of bod cause rapid depletion of the dissolved oxygen in the river water. The chemical oxygen demand (COD) found to be higher at SB-2 and SB-11. It shows that, both sampling has a high level of the pollutant in the water   COD by referred to the chemical-decomposition of an organic and inorganic contamination. The higher level of COD indicated the higher pollution of water of while lower level of COD indicated low level of pollution of water at the study area (Waziri and Ogugbuaja, 2010).

5.2 Concentration of Heavy Metals (Zinc, Cadmium, Lead, Chromium, and Copper), in Bertam River, Cameron Highlands.

In this study, there are five types of heavy metals were investigated from the water sampling. However, the results of cadmium were below detection limit at all sampling points (SB1-SB14). According to the National Water Quality Standards for Malaysia, the concentrations of all heavy metals are within the acceptable value limit except for lead. There are six water samples that exceed the acceptable value limit for lead. The heavy metals input through anthropogenic activities would not only increase the total contents of the metals, but also changed the proportions of their chemical forms, which may result in the increase of potential environmental risk.

Some researchers (Romic et al. 2003; Krishna and Govil 2005) reported that the accumulation of heavy metals such as Pb, Cr and Zn is mainly affected by anthropogenic activities. The most important anthropogenic sources of lead is domestic sewage. In Cameron Highlands, the total population is approximately 30,000, the majority of whom are employed in agriculture and the leisure industry (Tourism Pahang Darul Makmur, 2016). The practice of discharging waste from agriculture industries and untreated domestic sewage into the river is continually going on that leads to the increase in the concentration of heavy metals in river water (Martin et al. 2015).

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According to Hernández-Romero et al., (2004), pesticide application methods used in the agriculture area, and only small part of the product effectively reaches the target, while the rest is carried by air or rain to contaminate land and, eventually, the water catchments. Such applications may result in the increase of heavy metals particularly Cd, Pb, and As (Atafar et al., 2010) .These long-lasting toxics are very strong to the external factors and preserve their toxic nature for long period. Pesticides and other chemical contaminants that enter water objects through agricultural runoff, storm water drains and industrial discharges may persist in the environment for long periods and be transported by water or air over long distances (Lomsadze Z. et al., 2016). Based on the result, it is indicated that Pb concentrations were increased in the water because of the pesticide application.

5.3 Physicochemical properties and concentration of heavy metals in water samples comparable to Malaysian National Water Quality Standard (NWQS).

In this study, all parameters are within the NDWQ standard except for turbidity and Pb concentration. High turbidity value was recorded in the Bertam River water samples where thirteen of the samples (13) exceed the standard value. The main reason was concluded by many researchers in their studies that the agricultural coverage and land pattern development strongly influenced the total suspended solids and turbidity in the water (Kibena et al., 2013, Mouri et al., 2013). Among the turbidities value, the lowest was observed at the SB-1 that located at the upper stream of the Bertam River.

As the station SB-1 is located at the mountainous forest, the water displayed a very low turbidities value. Similar results were obtained by Rasul et al. (2015) whereas the turbidity (NTU) at the mountainous forest is 0.00 to 0.01. According to Malaysian Department of Environment, farming activities in Bertam Valley were clearly affected the concentration of turbidity and total suspended solids (TSS) of Bertam River (DOE, 2008). Based on the observation during data collection, there are domestic waste in the river that may contribute to the contamination of the river.

For lead concentration, there are six sampling stations exceed the standard value. Abdullah et al. (2014) stated that the possible reason for high concentration of lead may come from all anthropogenic sources such wastewater discharged from residential area and application of pesticide since there was agricultural land, and domestic wastes observed at the downstream of this river. Selene et al., (2003) also stated that applications of fertilizers and pesticides for agriculture have contributed to a continuous accumulation of heavy metals in soils and water. Besides that the dissolution of plumbing. The improper installation of pipe for tap that are not suitability treated may contain lead resulting from an attack on Pb service pipes (Abdullah et al., 2014).

5.4 The comparison of physicochemical properties and concentration of heavy metals in water samples between upstream and downstream of Bertam River.

In this study, 9 sampling stations (SB 1 to SB 9) were classified as upper Bertam while 5 sampling stations (SB 10 to SB 14) were classified as the lower Bertam. The classification was made based on the elevation model of the river (NAHRIM, 2017). It shows that there are significance difference between upper and lower of the Bertam River for turbidity. The turbidity values showed different values between the upstream and downstream in which the highest turbidity was obtained at the downstream whereas the lowest value was obtained at station SB-1, which is located at the upstream. Furthermore, the turbidity was increased significantly from upstream to downstream. It is often a result after high rain fall due to silt, clay and suspended solids by interaction of rainfall, upstream erosion and sediment (Lee et al., 2016). The excess amount of suspended solid in water that resulting to high turbidity can also be an indicator of land erosion in the river catchment (Naubi et al., 2015).Futhermore, SB-14 shows the highest turbidity value since there is intensive agriculture. According to Malaysian Department of Environment, farming activities in Bertam Valley were clearly affected the concentration of turbidity of Bertam River (DOE, 2008).

5.5 Association between the physicochemical properties and heavy metals of Bertam River, Cameron Highland.

In this study, it shows a strong correlation between Pb with Cr (r=0.989), Zn (r=0.897). High correlations between specific heavy metals in water may reflect similar sources of pollution, mutual dependence and identical behavior during their transport into the river system (Li et al. 2009; Chen et al. 2012; Suresh et al. 2012). In this study, findings show all the heavy metal except for Cd was positively correlated with turbidity. Most of heavy metal pollutants do not have direct impact on the optical properties of water, however, their distributions influence the surrogate properties of water, and the turbidity of the water (Ritchie et al. 2003; Ritchie and Cooper, 2001). Generally, the transportation and distribution of heavy metals occur along with the suspended particles, especially, the fine particles, due to their binding capacity (Yuan et al. 2001), surface area and high cation exchange capacity (Liebens, 2001; Ujevic et al., 2000). Therefore, the concentration of TSS and turbidity can be used to indirectly assess the heavy metal (HV) concentrations in the water body (Herngren et al., 2005; Hallberg et al., 2007).

5.6 Health risk from heavy metals exposure via water consumption

As for health risk in this study, all heavy metal in this study did not show any significant health risk as the HQ is less than 1 for non-carcinogenic risk and the carcinogenic risk did not exceed the acceptable risk. Although all heavy metals did not posed any significant risk, the elements are still possible to create adverse health effect if the pollution sources such as agriculture waste, waste dumping keep increasing day by day in the river. In addition, high rate of drinking water intake by population also could increase the risk of exposure since intake rate is one of the variables in the HRA calculation (Ma et al. 2007).

This result is consistent with Lim et al. (2013) where the carcinogenic risk is within and acceptable range. Lim et al did a study on the in particular housing areas of Selangor. Besides that, findings in this study also similar to other studies by Maisarah et al., (2012), Maisarah et al did study on the health risk assessment of lead exposure in drinking water in two villages in Kuala Terengganu, Terengganu. These studies showed that there were no potential adverse effects from Pb intakes via drinking water

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

In conclusion, all physicochemical properties and heavy metals in this study did not exceeded the permissible concentration limit in Malaysian National Water Quality Standard (NWQS) except for turbidity and lead (Pb). There is a significance difference between upper and lower of the Bertam River for turbidity. Besides that, the concentration of all heavy metals except for cadmium shows a strong correlation with turbidity. This results indicates a significant influence of the concentration of heavy metals to the value of turbidity. In addition, Cu also positively correlation with Cr (r=0.648). In addition, Cr has low correlation with pH (r=0.075). Findings also shows strong correlation between Pb with Cr (r=0.989), Zn (r=0.897).This results indicates a significant influence of one heavy metals to another. Based on the findings, the concentration of all heavy metals did not posed any significant risks to adult or children.

6.2 Recommendation

6.2.1 Recommendation to protect water quality

There are several recommended ways to protect the quality of the Bertam River as well as the health of the population near to Bertam River, Cameron Highlands. Eventhough the risk is not significant but fr•quent monitoring and abhdfdditional health risk assessments are necessary for metal levels above the recommended limits in the future. Besides that, it is recommended that action plans are made by the responsible governmental agencies to coop with the proposed environmental protection activities and pollution minimization and rehabilitation. It is important to implement compatible policies and programs for improvement in domestic waste water treatment methods, in poor agriculture practices and in proper land use management for sustaining the water quality from further deterioration.

6.2.2 Recommendation for Future Research

For future study, the study should be include more physicochemical parameter and include many types of heavy metals. This is to ensure that the other physicochemical parameter and heavy metals are below recommended limit. The tributaries of Bertam River also should be included to know either the concentration of heavy metal is keep increasing or decreasing. In the future. In the future, risk calculation should be calculated by using primary data not secondary data. The primary data can be collected through survey.

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