Further Analysis on Quality of Drinking Water in State of Perak

by

Nurul Jannah Binti Mat Ali Napiyah

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the requirements for the
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CERTIFICATION OF APPROVAL

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Approved by,

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(Dr. Maziyar Sabet)

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

NURUL JANNAH BINTI MAT ALI NAPIYAH

ABSTRACT

Quality of drinking water from 10 sources was determined by analyzing parameters that could deteriorate the water quality. The parameters that were studied are pH, conductivity, total suspended solid (TSS), total dissolved solid (TDS) and heavy metals such as Cd, Cr, Pb, As, Hg and Sn. The metals were analyzed using standard methods approved by APHA. The results from the analysis were then compared with drinking water quality standards such as guidelines from WHO, USEPA and local standards that are NDWQS and NWQS. All parameters were found to be within the limit set by those bodies except for Sn in samples from certain locations that had exceeded the maximum allowable concentration. Thus, water from all the locations were found to be safe as drinking water by means of all the parameters analysed were within the standard limit. Exception is made to the exceeding of Sn concentration in five samples because Sn is not considered to be primary or secondary pollutant for drinking water and possessing very low risk of harming human health.

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LIST OF ACRONYMS AND ABBREVATIONS

As : Arsenic
Ag : Argentum
B : Boron
Ba : Barium
Ca : Calcium
Cd : Cadmium
Co : Cobalt
Cu : Copper
Cr : Chromium
Fe : Iron
Hg : Mercury
K : Potassium
Li : Lithium
Mg : Magnesium
Mn : Manganese
Na : Sodium
Ni : Nickel
Pb : Lead
Zn : Zinc
APHA : American Public Health Association
BG : Batu Gajah
BU : Bandar Universiti
BSI : Bandar Seri Iskandar
EDTA : Edtech Associates Sdn. Bhd.
FAAS : Flame atomic absorption spectrometer
GFAAS : Graphite furnace atomic absorption spectrometer
ICP-MS : Inductively Coupled Plasma- Mass Spectrometer
ICP-OES : Inductively Coupled Plasma – Optical Emission Spectrometer
MW : Bottled Mineral Water
NDWS : National Water Quality Standard
NDWQS : National Drinking Water Quality Standard
PWB : Perak Water Board
RO : Water Dispenser Machine
SDWF : Safe Drinking Water Foundation
SIP : Siputeh
TDS : Total Dissolved Solid
TM : Taman Maju
TRO : Tronoh
TSS : Total Suspended Solid
UTP : Universiti Teknologi PETRONAS
WHO : World Health Organization

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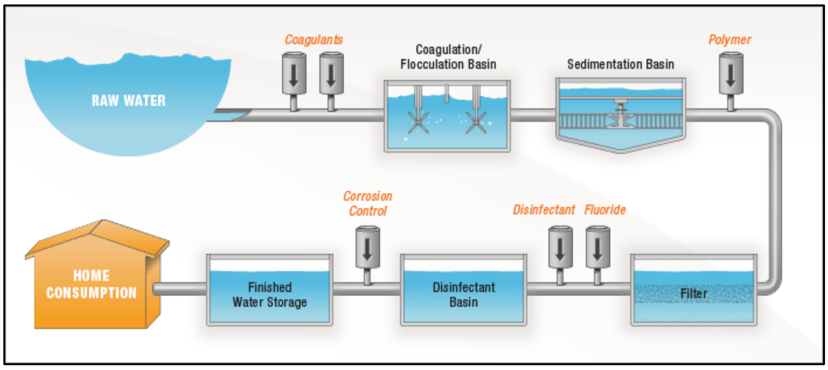
CHAPTER 1

INTRODUCTION

1. BACKGROUND OF STUDY

1.1 Drinking water

Surface and ground water are treated and processed to produce safe and healthy water for community use. Water used for household supplies is commonly defined as domestic water. In Malaysia, raw water resources are from surface water streams, lakes, rivers and man-made dams. This water will need to go through several processes in order to be safely consumed as drinking water and other purposes. Figure 1 shows the typical system of conventional water treatment processes. During coagulation and flocculation process, chemical such alum and carbon dioxide would be added to assist the particles to stick together. Then, in the sedimentation basin, the heavy particles would settled down and sediment be removed. Clear water appears after the filtration process where it will go through layers of filters made from sand and coals. Water is disinfected using fluoride or chlorine in order to kill bacteria, viruses and microbes.



Source: The treatment processes, www.denverwater.org

Figure 1: Conventional water treatment processes

In some system, pH controller would be added to give alkalinity to the water and to prevent corrosion of water distribution piping system. Treatment plants supposedly to produce domestic water quality that fits the quality of drinking water (Drinking Water Quality and Health). Although this system is ensuring the cleanliness of the water but it could be contaminated without any notice.

1.1.1 Contaminants in drinking water

Water quality and suitability for use is determined by taste, odour, colour and concentration of organic and inorganic matters (Dissmeyer, 2000). Water could carry impurities naturally. It may be due to contacts with the impurities along the flow. Water would absorb contaminants and chemicals from its surrounding structures (Ryan, 2009). These could come from usage of pesticides and fertilizers by agricultural activities that may have caused content of nitrates to seep into water sources. Then, chemicals spills and improper disposal of wastes may cause hazardous materials to enter streams and accumulate in the soil. Sooner or later, rain water will wash off the substances into the rivers. Other source of contamination may be from the acid rain that is the result of air pollutant. Table 1 shows the summarized sources of possible chemicals contamination in drinking water as described in the Guideline of Drinking Water Safety by World Health Organization (WHO).

Table 1: Sources of Chemical Contaminations

Sources of Chemicals	Example of Sources
Naturally occurring	Geologic locations, climates, rocks and soils
Industrial sources and human dwellings	Mining, manufacturing and processing industries, sewage, solids waste, urban runoff and fuel leakages
Agricultural activities	Manures, fertilizers, pesticide and intensive animal practices
Water treatment or materials in contact with drinking water	Coagulants, DBP’s and piping material
Pesticides used in water for public health	Larvicides used in control of disease from insects
Cyanobacteria	Eutrophic water bodies

Impurities can be considered to be contaminants at certain levels. According to Drinking Water Quality and Health from Safe Drinking Water Foundation (SDWF), contaminant is any substance or matter that can give adverse effects physically, chemically, biologically or radio logically to water. Introduction of this contaminant makes the water not suitable for any usage. SDWF had also added that contaminant can be categorized to microorganisms, radio nuclide, inorganic, organic, disinfectant and disinfectants by-product. Table 2 shows categories of contaminants and examples.

Table 2: Categories of contaminants and examples

Contaminants	Example
Microorganisms	Protozoa parasite, algae, bacteria, virus
Inorganics	Mineral in origin such as Lead (Pb), Tin (Sn) and Mercury (Hg)
Organics	Man-made or natural materials with carbon molecules such as Xylenes
Radio-nuclides	Radioactive materials such as Uranium (Ur)
Disinfectants	Additives in water to control microbes such as chlorine
Disinfectants by-product	Additives that react with natural matter in water such as trihalomethanes (THA)

Microorganism enters lake and rivers from sewage and animal waste. Inorganic contaminants could be sourced from the industrial waste, landfill and corrosion of pipes and plumbing system. Contaminant such as arsenic (As) may result from the runoff of the electronic and glass production. Meanwhile, cadmium (Cd) and lead (Pb) contamination may result from corrosion of plumbing system and erosion of natural deposits. Hence, it is possible for water to be contaminated with these substances as it is widely exposed to vulnerable surrounding and numbers of sources of contamination.

1.1.2 Heavy Metals and Health Problems

Chemical contamination in drinking water has shown to harm human’s health after prolonged exposure (Guideline to Drinking Water, 2008). Although, existence of certain substances in the water is known, severe problems would rise when the presence of chemicals which possess high health risk are unknown but widespread. As contaminants come in different types and resources, they also give different adverse effects to human. Generally contaminants would bring the following effects:

i. Aesthetic effect that could lead to give unlikeable taste or odour
ii. Cosmetics effect that contributed to unappealing appearances
iii. Acute health effect which occurrence of health problems after hours or days one person consumed the contaminants
iv. Chronic health effect that is occurrence of health problems after a long term exposure

Point i and ii could bring the water to be not drinkable of the appearance and taste. Meanwhile, effects to the health problems as viewed in point iii and iv that draw the attention of researchers and consumers. Parasite, bacteria and viruses would commonly cause gastrointestinal diseases. Meanwhile algae in excessive amount would affect the colour and odour of the water. Some type of algae is known to produce poison that could attack liver and nervous system. Radio nuclides that resorted from decay and erosion may lead to cancer diseases and some such as Uranium lead to kidney problems. While, organic contaminants such as methoxychor and benzo(a)pyrene (PAH's) have the potential health effect of reproductive difficulties.

Inorganic chemical contaminants holds greater portion as contaminants in drinking water compared to organic chemical contaminants (Fawell, 1993). Although most of the substances exist naturally in water, but several are from human activities that has been mentioned in the previous section. Part of inorganic chemicals is minerals that could be considered as heavy metals. Heavy metals tend to accumulate in organs and nervous system. These substances will interfere with the organs normal functions. Therefore, substances such as Pb, As, Mg, Ni, Cu, Zn and other metals have received major attention due to their potential of affecting health problems.

According to Al-Saleh (1996), occurrence of human health problems such as cardiovascular diseases, kidney related problem, neurocognitive diseases and cancer are related to the traces of metals such Cd and Cr as shown in epidemiological studies. Table 1.3 below shows some of the heavy metals and associated health problems. Viewing to the effects that these metals could lead to, chronic exposure at even low concentration could lead to adverse health effects (Simone et al., 2012).

Table 3: Heavy metals and associated health problems

Elements	Health Concerns	Cited Sources
Arsenic	• Cardiovascular, skin pathology, skin cancer, evidence of casualty • Dermal lesions, bladder and lung cancer	• Fawell (1993), WHO (2008) • SDWF • EPA
Cadmium	Accumulates in kidney and has long biological half-life and damage the kidney	• EPA • WHO (2008) • SDWF • Al-Saleh (1996)
Chromium	• Cr(III) and Cr(IV) carcinogenic • Allergic dermatitis	• WHO (2008), Fawell (1993) • Dissmeyer (2000)
Lead	• Delay in physical and mental development for infant and children • Kidney problem and high blood pressure for adults • Toxic to central and peripheral nervous system including subencephlopathic neurological and behavioral effects • Carcinogenic	• Dissmeyer (2000), WHO (2008) • WHO (2009)
Mercury	• Kidney damage • Haemorrhagic gastritis and colitis • Benign tumor at sites where tissue is damage • Genotoxic activity	• Dissmeyer (2000), WHO (2009) • WHO (2009)
Tin	• Acute effects: Vomitting, diarrhea, fatigue • Chronic effects: Liver damage, depression, malfunction of immune system, brain damage	• Health effects of tin

1.1.3 Drinking water quality standards

WHO has set guidelines for drinking water quality that can be followed by national drinking water quality bodies in various countries. For instances, in Malaysia, an established standard had been set up that is National Drinking Water Quality Standard (NDWQS) that must be followed by water services providers for each state such as Lembaga Air Perak. NDWQS has fixed the limit for substances in water that may cause health problem or disrupt physical senses of consumer. This ensure only safe water reached the consumer. Table 4 shows the concentration limit for inorganic elements particularly heavy metals in drinking water set by NDWQS. The limit set by NDWQS is based on the guideline provided by WHO. Thus, the values are the same for both standards.

Table 4: Concentration limit of heavy metals in drinking water set by NDWQS

Element/ Substance	Symbol/ Formula	Concentration (mg/L)	Element/ Substance	Symbol/ Formula	Concentration (mg/L)
Aluminum	Al	0.2	Magnesium	Mg	150
Antimony	Sb	0.005	Manganese	Mn	0.1
Arsenic	As	0.01	Mercury	Hg	0.001
Barium	Ba	0.7	Molybdenum	Mb	0.07
Boron	Bo	0.5	Nickel	Ni	0.02
Cadmium	Cd	0.003	Selenium	Se	0.01
Chromium	Cr	0.05	Silver	Ag	0.05
Copper	Cu	1	Uranium	Ur	0.002
Cyanide	Cy	0.07	Zinc	Zn	3
Iron	Fe	0.3			
Lead	Pb	0.01			

The quality of water consumed by a community could be determined by analyzing the content of the water. By doing so, the obtained results can be compare to the concentration limit set by the standards. Identification of metal elements that have concentrations exceeding the limit could further pin point the contaminants and at the same time determines the safe level of the water. The community should be supplied with safe water. According to Andrews (2009), experts have estimated between 500000 and 7 million people in the United States have health problems because of tap water. Hence, the study is an initiative to ensure the safe level of the drinking water supplied to the people within the research areas.

1.2 Problem Statement

Low quality drinking water maybe polluted with excessive concentration of heavy metals. Severe exposure to the elements could endanger the community in term of the acute and chronic effects to the health. Despite from that, it could also affect productivity of crops. As tap water is the main source of water for the community, it is very crucial to access the quality of the water that the consumer received. Hence, further analysis on drinking water samples will be carry out aligned to the prior research work on quality of drinking water in state of Perak.

1.3 Objective

The objectives of this study are:

i. To determine concentration of heavy metals such as Lead (Pb), Mercury (Hg), Cadmium (Cd), Chromium (Cr) and Arsenic (As) in drinking water for at least 10 places in state of Perak.

ii. To study the quality level of the samples by referring to relevant international and local standards.

1.4 Scope Of Study

The study would cover residential areas of Ipoh, Batu Gajah, Bandar Universiti, Taman Maju, UTP, Siputeh, Seri Iskandar and Tronoh. Drinking water samples would be taken from the specified areas. Despite from tap water other sources of drinking water such as water dispenser machine and bottled mineral water will be included for the quality analysis.

CHAPTER 2

LITERATURE REVIEW

2. WATER SUPPLY

In Malaysia, clean water supplies are managed by state-by-state basis (Azrina *et al*, 2011). It is also stated in the Federal Constitution of Malaysia that it is part of state government responsibilities to manage water. This includes the catchment of the raw water resources, treatment, distribution and maintenance of the system. Previously, these responsibilities are taken up by Public Work Department of each state. Nowadays, several agencies are set up to manage water supply to the community. There is State Water Supply Department for states such as Pahang, and Terengganu. Water supply is under the responsible of State Water Board for states of Perak, Melaka and Pulau Pinang. Meanwhile, state such as Selangor and Johor manage by State Water Company. There are still states that remained to stick with the state public work department such as Kedah and Perlis.

2.1 Perak Drinking Water Supply

2.1.1 Perak Water Board (PWB)

Perak Water Board (PWB) is the agency that responsible for supplying clean water to whole of Perak. They are responsible of fulfilling the need of clean water to the rural and urban areas. This includes the trade and industrial area. The board is divided accordance to the region that it is managing. The regions are Northern region, Western region, Central I region, Central II region and Southern region (PWB,2012). Each of the regions is headed by the Regional Manager. Meanwhile these five managers are under the supervision of Chief Executive of PWB that acts as the

General Manager. This agency consists of Administration, Operations, Development, Quantity Surveyor, Electrical and Mechanical section and Laboratory Department. These departments are mainly the one that looked after of the whole agency. The headquarters of PWB is situated in Ipoh, Perak.

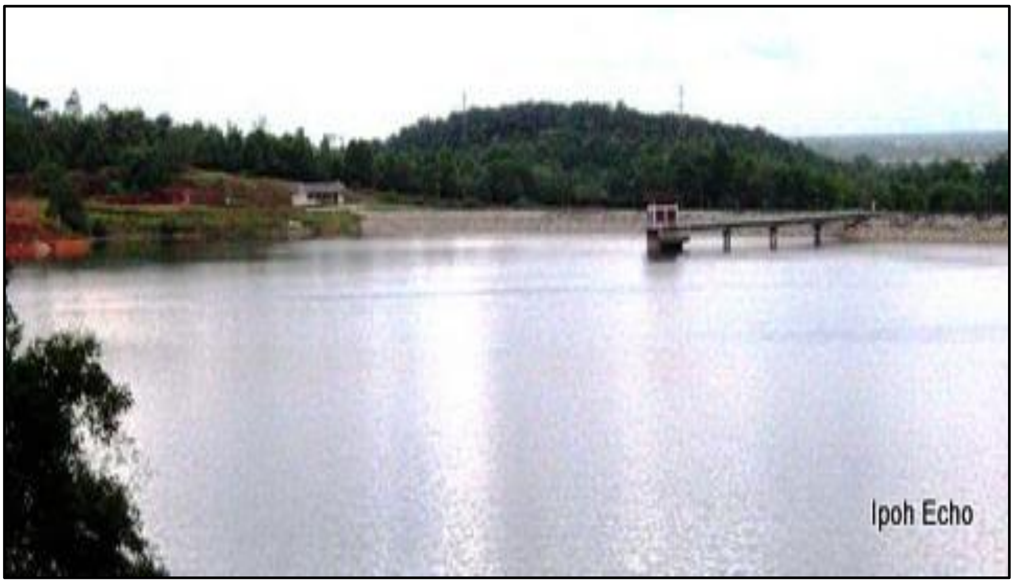
2.1.2. Perak Water Resources

The raw water resources for the use of Perak states are taken from various rivers in the state alone. The geographical location of Perak accommodates the source for raw water. Land in Perak is made up of the stretches from mountains from Banjaran Titiwangsa where all the rivers root from here. Banjaran Titiwangsa also known as the Main range is the backbone of Malaysia where it stretches up to 500km along Peninsular Malaysia to the border of Thailand. Rivers originated from these highland forests which it satisfies the need of almost 90% for domestic, agricultural and also industrial usage and naturally a water reservoir (The Malaysian Rainforest, 2012). In fact, Banjaran Titiwangsa is also the main water resources throughout Peninsular Malaysia.

The location of the intakes mostly is remote and far from development lead to a clean and unpolluted water sources. Thus, ordinary water treatment system would be adequate to make the water drinkable. For state of Perak, the main resource of water is Perak River and followed by mountain waters. Currently, the board is operating two dams that are Sultan Azlan Shah (Figure 2) dam (situated in Ulu Kinta, Ipoh and Air Kuning (Figure 3) dam in Taiping.

Source: www.eng.usm.edu.my

Figure 2: Sultan Azlan Shah Dam, Ulu Kinta, Ipoh, Perak



Source: ipohecho.com.my

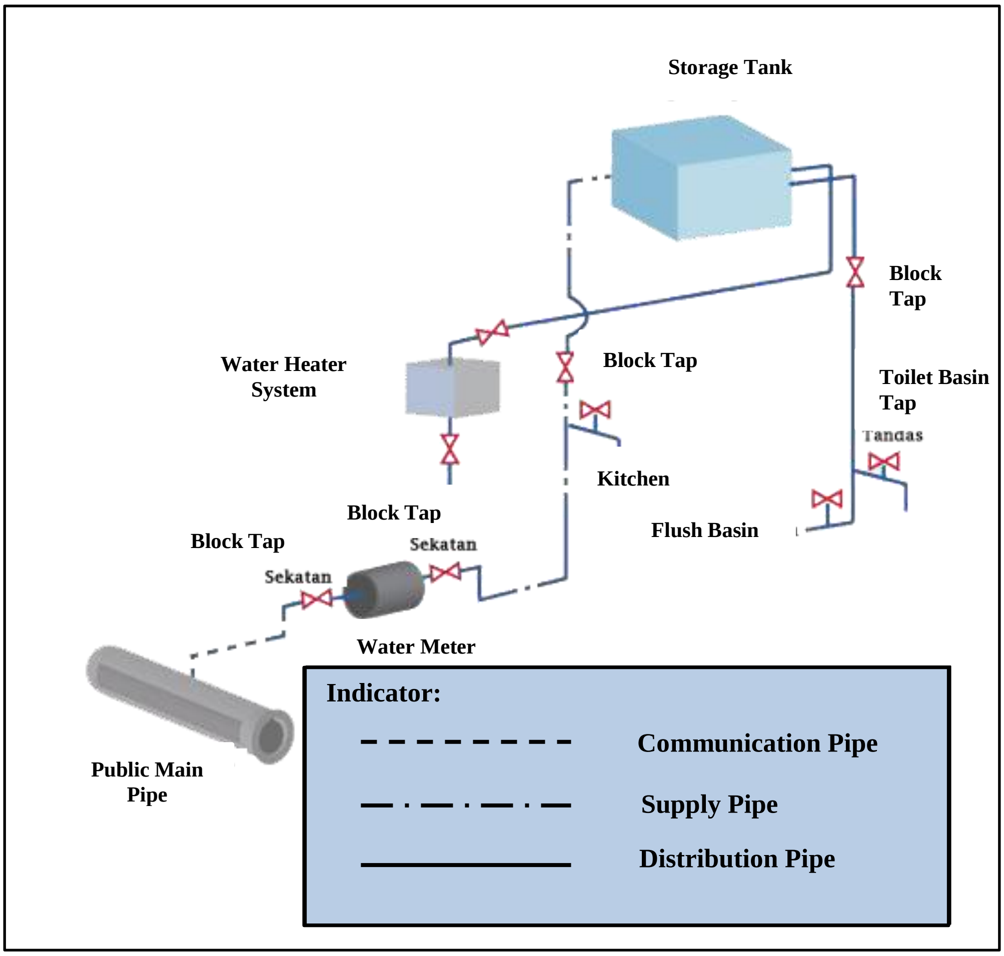
Figure 3: Air Kuning Dam, Taiping, Perak

PWB has total of 47 water treatment plants, and hold a capacity of 1774 mld (million litres per day). The current production of plants is 1081 mld with the consumption of 738 mld. The water distribution is 100% to urban areas and 98% to the rural areas with the pipeline system stretched to 10792 km (Wong, 2012).

2.1.3 Treated Water Distribution

The raw or untreated water would need to go through standard water treatment processes. Although water from the water resources mentioned above is in a good quality due to the geographical location, further treatment would be required to adhere to the drinking water standard in Malaysia. This treatment also has the purposes to make the water drinkable where odor and undesired taste would be eliminated. Mentioned by PWB, the standard treatment system would include screening, coagulation and flocculation, sedimentation, filtration and disinfection processes. The treated water would be kept in tanks water ponds for distribution to the consumer.

From the water tanks and ponds, connected piping systems would be used to reach residential and business areas. The following Figure 4 shows the internal piping plan of water distribution to the consumer. Drinking water from the water treatment plant would be transferred through the public main pipe. Then, from there it will be distributed into the premises by communication pipes through the water meter. Then, supply pipe would flow the water to storage tank and to the tap at the kitchen. This is the direct source of the water from the main pipe. Then, from the storage tank will be connected to other taps and water basin by distribution pipes.



Source: www.lap.com.my

Figure 4: Internal Piping Plan

2.2 Previous Works on Drinking Water Analysis

Contaminations of water with metals will lead to acute and chronic effects. Therefore, awareness has been raised from this matter in ensuring the quality of water typically drinking water. Studies on contents of inorganic and organic elements in drinking water were widely done internationally. This is because inorganic and organic substances are the sources of contamination for drinking water (Fawell, 1993). As tap water is directly consumed by community, contaminant could spread easily and directly into human's body. High concentration of some unwanted substances in water will risk human long term exposure.

There are research works that have been carried out to determine the safe level of drinking water. Other than, studying on the physical properties such as pH, conductivity and turbidity of the water that relates to water quality, various works have also been done in identifying concentration of inorganic elements particularly heavy metals in the water samples. This study is mostly referred to the work done by Siti Hajar A. and Rahmanian N. (2012) as it is a continuation of the research work done. Reported by the authors, the study had done complete analysis on the drinking water samples covering from pH, temperature, conductivity, turbidity, total suspended solid (TSS), total dissolved solid (TDS) and heavy metals concentration. The concentration of metals measured was Cu, Mg, Zn and Fe. The result obtained showed that all the parameters studied were within the standard limit for drinking water quality set by MNDWQS and WHO. Current study would be focusing on other elements that have been listed in the drinking water quality standards such as Cd and Cr. In research works such as Pinar *et al.* (2012), Sardar *et al.* (2012), Said *et al.* (2011) and Rosa *et al.* (2010) substances that always have concentration exceeding the national and international standards are As and Pb. Meanwhile, in the same work done by the authors explained that, amount As and Pb are not traceable using the AAS. Therefore, in the current work, ICP-MS would be used to quantify the concentration of elements due to lower detection limits of the equipment. This is done to ensure that the concentration of heavy metals in the scope of the study can really be determined. By doing so, the author could further clarify that the water quality level is within the standards set by WHO and NDQWS.

The work on justifying the safe level of drinking water in Malaysia had also been done by Azrina *et al.* (2011) and Hasbiyana (2008). Work of Azrina *et al.* (2011) is on determination of concentration of major inorganic elements in drinking water samples from 12 states of Peninsular Malaysia. Meanwhile Hasbiyana (2008) had focused on comparing content of heavy metals in industrial, agricultural and residential areas of Shah Alam, Selangor. Both of study had used flame AAS to measure concentration of Na, Mg, K, Ca, Fe, Cu and Zn (Azrina *et al.*, 2011); Cu, Cd and Pb (Hasbiyana, 2008). Added by Azrina *et al.* (2011), graphite furnace AAS was used to determine Cr, Ni, As, Cd and Pb. For Mn, ICP-OES had been used. From the study done, concentration of all elements was below the international limit except for Fe and Pb in Kelantan and As in Perlis. Explained by the author, excessive concentration of Fe and Pb in Kelantan may be due to the erosion of natural deposit and corrosion of household plumbing system. Added to that, As concentration higher than the limit in Perlis may cause by close proximity of the areas to rice cultivation. Used of chemical fertilizers caused the level of As higher in rice grain and soils. On the other hand, concentration of all the heavy metals in the study of Hasbiyana (2008) had exceeded the NDQWS. The author concluded that sampling locations has significance effects on the level of heavy metals in tap water.

Based on the studies, concentration of heavy metals in drinking water varies from one location to another. Industrial areas may have higher contaminants in the water than in rural areas. However, residential areas and villages do not guarantee that the drinking water is free from heavy metals contaminations. Source of contamination may be from agricultural activities, low maintenance of water distribution system and others. Referring to the present study that would be targeting areas in Kinta and Perak Tengah districts that mostly were known to be tin mining areas. This could be seen by observing a lot of abandoned tin-mining pools scattered throughout the areas. Study has shown that disused tin-mining areas pose potential health hazards of having high amount of inorganic arsenic and other heavy metals (Yusof *et al.*, 2001). Hazardous substances may wash away by rivers that pass these areas. The authors further elaborated that most treated water comes from these rivers where they become the water intake point of raw water to the water treatment plant.

Bottled drinking water does not always be better than tap water (Rosa *et al.*, 2010; Mona *et al.*, 2008). The authors mainly compared content of two different drinking water sources that are bottled water and tap water. Mona *et al.* (2008) in their work of assessing chemical content in drinking water, they compared both results with both local and WHO standards. Drinking water samples were taken from tap waters and commercialized bottled water in Dakahlia Governorate, Egypt. Findings show that tap water samples contain higher concentration of Pb, Zn, As, Cd and Se whereas bottled water samples contained greater amount of mercury and magnesium.

On the other hand, study done by Rosa *et al.* (2010) had also compared drinking water from the same sources but the samples were taken from Italian municipal tap water and bottled natural drinking water. The authors had used ICP-OES to determine concentration of Ca, K, Mg and Si. ICP-MS was also used to analyze traces elements such as Cd, Cr, As and Pb. The results obtained concluded that bottled water has higher concentration of As, Sb, B, Ba, Li and U than found in tap water. Reasoning behind this finding is that bottled water usually mineral water that is enriched with the elements due to interaction of water-rock processes. Thus, in the present study, comparison between different types of drinking water resources would also be taken into account. Water dispensing machine that utilizes reverse osmosis process and bottled drinking water will be an addition to the tap water samples. These sources are very popular among consumer with the perception of them to be safer and healthier to be consumed than tap water. Relating to the study of Siti Hajar and Rahmanian (2012) that had also worked on these samples, the same sources would be included in the current study but analysis would be on different elements.

Previous research works on investigating quality of drinking water from various countries had proven that concentration of heavy metals indeed plays an important criterion in determining the safety level of drinking water. These concentrations must be within the limit set in drinking water quality standards set by WHO and according to Malaysia’s standard that is NDWQS. Determination of concentration of heavy metals could lead to prediction of health risk exposure for the population of the area which the research was covered (Said *et al*, 2011; Hanaa *et al.*, 2000). Works such Sotirios *et al.* (2008), Clemens *et al.* (2003) and Dissmeyer (2000) had stressed on the significance of determining the concentration of traces element in their works. Therefore, this aspect is really important in determination of the safety level of the drinking water. As the results of the analysis would be crucial for the community where they have the right to have the information of the water quality they consumed (Rosa *et al*, 2010).

2.3 Methods Used For Quantification of Elements In Water

Methods of heavy metals quantification used in those papers were different from one another but generally all the instruments used are spectrophotometer equipment. Table 5 summarizes the common equipment used by previous research works. Most literatures found to be using AAS as it is a technique that is much well-known. Despite from it is easier and cheaper to operate.

Table 5: Common equipment used for analyzing elements in water samples

Equipment	Element analyzed and related works
Flame Atomic Absorption Spectrophotometer (FAAS)	- Cu, Fe, Mg and Zn (Siti Hajar & Rahmanian., 2012) - Cu, Ca, Fe, K, Mg, Na and Zn (Azrina *et al.*, 2011) - As (Pinar, Aysun, & Sait, 2009) - Cu, Cd and Pb (Hasbiyana, 2008)
Graphite Furnace Atomic Absorption Spectrophotometer (GFAAS)	- Cd, Cu, Fe, Ni, Pb and Zn (Sardar *et al.*, 2012) - Cu, Cd, Co, Cr, Mn, Ni, Pb and Zn (Said *et al.*, 2011)
Inductively Coupled – Optical Emission Spectrophotometer (ICP-OES)	- As, Cd, Cr, Ni and Pb (Azrina *et al.*, 2011) - Ca, K, Mg and Si (Rosa *et al.*, 2010) - Be, Cd, Co, Cr, Cu, Mn, Ni, Pb, V and Zn (Pinar, Aysun, & Sait, 2009) - Pb, Cd, Cu, Mo, Ni and Cr (Hanaa, Eweida, & Azza, 2000)
Inductively Coupled – Mass Spectrophotometer (ICP-MS	- As, Cd, Cr and Pb (Rosa *et al.*, 2010) - As, Cu, Ni, Mn, Zn and Se (Tarit, Hirsoshi, & Masanori, 2003)

However, for element such As, preferred technique would be using ICP. Referring to the standards set by WHO, concentration of substances such as Cd and Hg in drinking water need to be below than 0.003 and 0.001 mg/L. Therefore, equipment that will be used to quantify these elements should have superb capability of measuring low concentration of elements.

The basic concept between the AAS, ICP-OES and ICP-MMS is the generation of free atoms of the element that is interested in (Robert, 2004). The difference between the equipment would be in the source used to generate the free atoms. For AAS, either flame (combustion of fuel and oxygen) or utilizes graphite furnace. Instead atomic or ion atomizer such as plasma is used in ICP-MS and ICP-OES. The author added, ICP equipment utilizes the interaction of an intense magnetic field that produced when radiofrequency (RF) passed through copper coil. Differentiating ICP-MS and ICP-OES is through the position of the plasma and ions that it generates. Plasma torch is placed vertically and generates photons of light. Meanwhile in ICP-MS, the plasma is horizontal and used to generate positive charged ions. Having this characteristic put the equipment to have higher detection capability compared to ICP-OES. Attached in Appendix 1 is the diagram of basic instrumental components of AAS, ICP-OES and ICP-MS. Included in the appendix would be the picture of each of the instrument.

Equipment selection process could be done by comparing criterion such as analytical detection limit and sample throughput .For detection limits of the equipment, ICP-MS has the highest detection limit that covers until the unit of part per trillion (ppt). This would be really beneficial to the research where it has the objective of determining the unknown concentration of heavy metals in the samples. Therefore, most sensitive equipment can be used to analyze the sample where it could detect elements even at the lowest concentration. In the work of Siti Hajar and Rahmanian (2012), mentioned that Hg, Pb and As were not detected by FAAS due to the low detection limit of the instrument used. Meanwhile, sample throughput can be defined as the number of samples that can be analyzed each time. For FAAS, only one element per sample could be detected each time. Other elements could also be detected but the light sources and optical parameters needed to be change. This would cause a longer time required to analyze large number elements and samples. ICP-OES and ICP-MS have the same sample throughput where they allow multi-element detection in a specific sample. For samples that have many analytes to be determined, ICP-OES and ICP-MS techniques are preferable than AAS.

The inability of AAS to detect As, Hg and Pb in drinking water samples from state of Perak had been observed through the work of (Siti Hajar & Rahmanian, 2012). Therefore, in the earlier planning of present study, the author has planned to improvise the analyzing technique by using equipment that can detect lower concentration of elements such as ICP-MS. Furthermore, a wider range of detection limit is suitable for the study which elements have quite different limit set by the standards. In other words, concentration of some elements in the samples may have vast different from one another. Thus, wider detection limit allows all elements to be detected despite having the lowest concentration. Other method such as using GFAAS is also expected to be able to perform well in detecting low concentration of some metals.

Selection of equipment is highly dependent on the equipment detection limit, the type of metals to be analyzed and sensitivity of the metal itself in order to be detected at the specified wavelength. As done by researches, metals with expectation of having low concentration in the samples will analyzed using higher sensitivity equipment such as ICP and GFAAS. As one sample may have different concentration of metal, equipment with wider range of detection limit would be chosen. Other than that, equipment availability and cost of analysis would also be considered before choosing specific equipment. Analysis using ICP which is a high performance spectrophotometer would cost higher than AAS. Due to the high acquiring cost of the equipment itself has cause it to be only available in limited laboratories or institution. Experience and skills are needed in order to operate GFAAS due to the sensitiveness of the equipment. Lack of skills can cause the equipment to be instable and produce inaccurate results.

CHAPTER 3

METHODOLOGY

3. PROJECT METHODOLOGY

This section will discuss on the project acquisition processes. This will include the project flow chart, chemical, apparatus and equipment needed for the laboratory and on-site works. Procedures for carrying on both of the works will also be explained.

3.1 Project Flow

The project will be run with the following planning. Some of the plans are actually overlapping or in other words will be done simultaneously. Alongside with preparation for the project proposal, requisition of chemicals, apparatus, workstation and selection of sampling sites were done. With complete preparation, samples were collected and preserved. Later, they will be analyzed using suitable equipment. Then, the data will be interpreted and findings are reported. Between these activities, necessary visits were made to PWB to collect data and information for the purpose of in-depth knowledge of the project. Figure 5 shows the project flow chart.

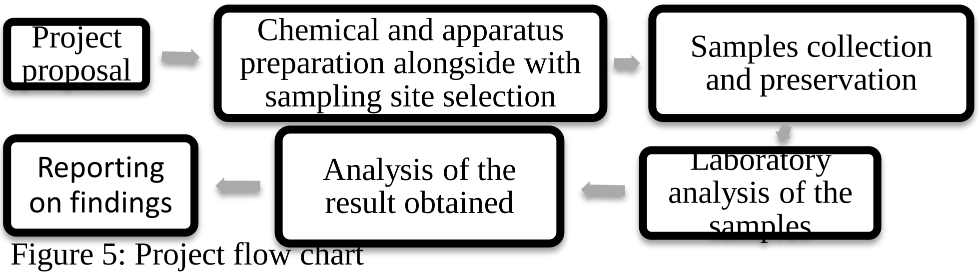


Figure 5: Project flow chart

3.2 Materials Required

The lists of chemicals substances, apparatus and equipment needed for this project work are stated in Table 6.

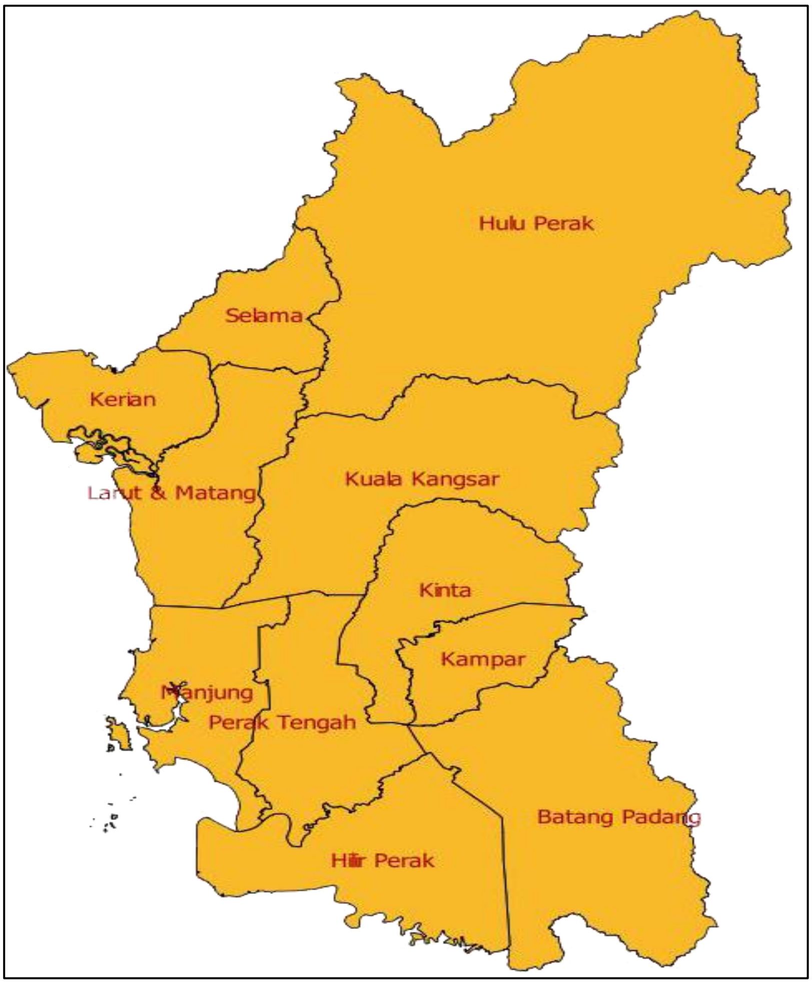
Table 6: Chemicals, Apparatus and Equipment for experimental work

Chemicals	Apparatus	Equipment
Concentrated nitric acid	Polyethylene bottle 500mL and 250 mL	pH meter
Standard stock solution of As	Beaker 500mL and 250mL	Conductivity meter
Standard stock solution for Cd	Plastic test tubes 50mL	Turbidity Meter
Standard stock solution for Cr	Whatmann Microfibre Filter GF/C 47mm	Muffle Oven
Standard stock solution for Pb	Volumetric Flask 1L	Flame atomic absorption spectrophotometer (FAAS)
Standard stock solution for Hg	Vacuum Pump	Vacuum Pump
Standard stock solution for Tin		Filtration Apparatus
		Weighing Scale

3.3 Experimental Procedures

3.3.1 Resampling and Sampling Location

Relating to Siti Hajar and Rahmanian (2012), drinking water samples are already available that were taken in month of September 2012. However, it was not preserved accordingly. Any unpreserved samples can only be used within 14 days after the samples are taken (Lesley, 2009). Therefore, in ensuring the samples are relevant and can provide accurate quantification their content, resampling of the samples will be done. The samples were collected randomly at 10 different sources. Residential and institutional areas are chosen because it is where most population is and water usage is huge. Quality of the water is crucial as it is consumed by a large community. Eight of the samples will be from tap water situated in residential and institutional area. These locations are situated in Kinta and Perak Tengah district as shown in Figure 6. The locations will be the same as in the previous work has done that are Ipoh, Batu Gajah, Siputeh, Seri Iskandar, Bandar Universiti, Taman Maju and Tronoh. Figure 7 indicates the location of the samples in the map of Perak. The water from these locations was taken from tap water in premises that are open for public such as restaurant and private houses. The other two sources of samples were from water dispenser machine such as reverse osmosis and bottled mineral water.



Source: Perak Geographic Informational System, http://www.perakgis.my/v1/

Figure 6: Map of Perak Districts

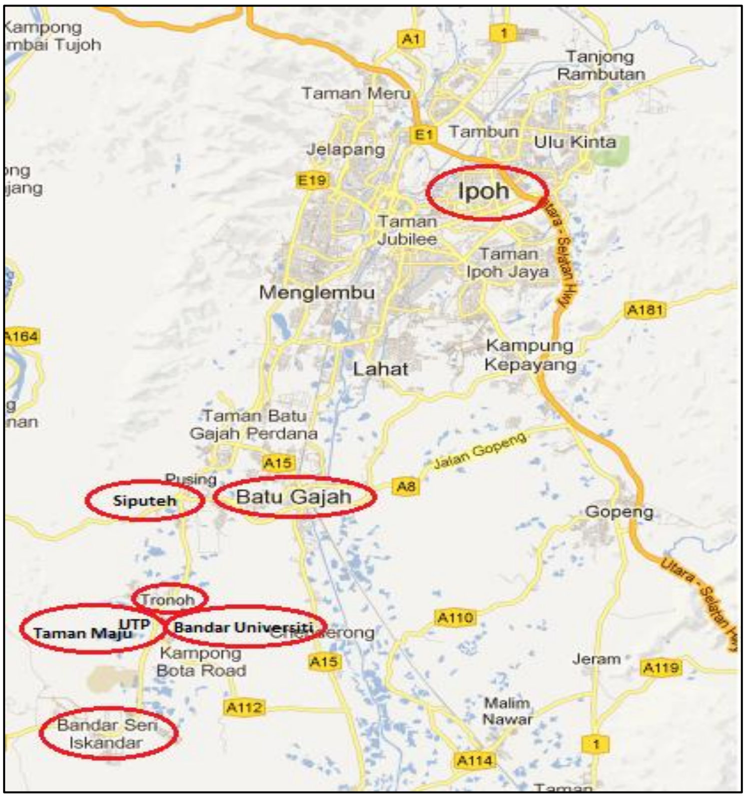


Figure 7: Sampling locations

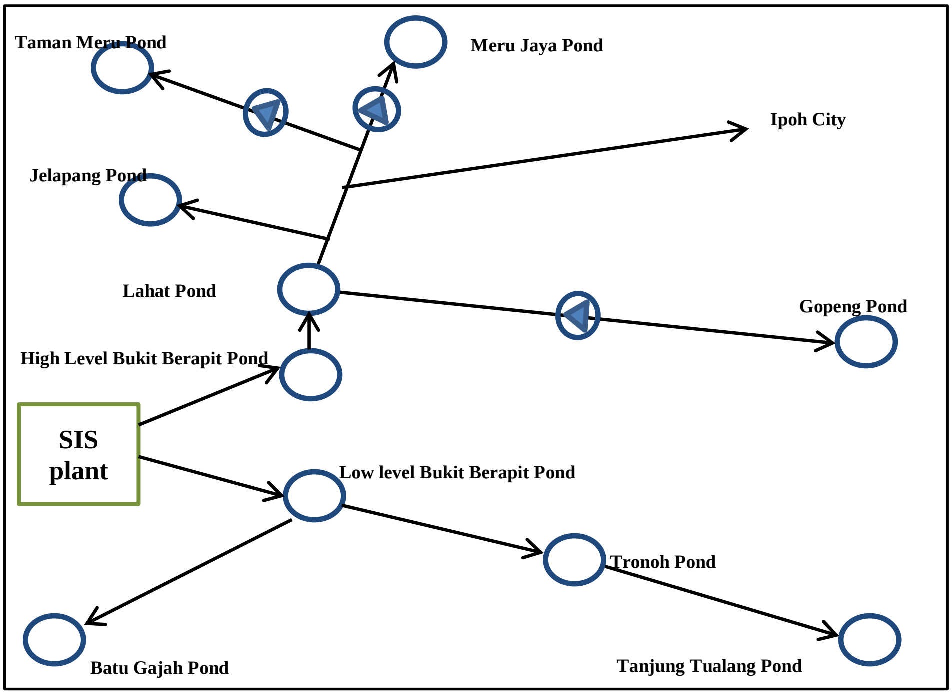
Population of each location is shown in Table 7. Size of population for each of the sampling location indicates the number of people would be affected if the drinking water they consumed daily is not safe. From the stated value, the largest population would be from Ipoh with 434 204 people. On the other hand, the least population is Siputeh with 429 people. For sampling location of Taman Maju, Bandar Universiti and Bandar Seri Iskandar, they are considered to be the total population of 16 510.

Table 7: Sampling Location Population

Location	Population (people)
Ipoh	434 204
Seri Iskandar	16 510
UTP	7324
Batu Gajah	6 738
Tronoh	1 498
Siputeh	429

3.3.2 Sampling Location Data Collection

As mentioned in the earlier subsection, the samples will be primarily from locations in two districts of Perak which is the Kinta and Perak Tengah district. Therefore, a research was made on the source of the water taken from the locations. The water sources for each sampling locations would be from specific water treatment plants. Therefore, Table 8 summarizes the sampling locations and the sources of the water. From the table it is shown that the water source of 1) Bandar Universiti, 2) UTP, 3) Water dispenser Machine, 4) Taman Maju and 5) Bandar Seri Iskandar would be from Kg. Senin water treatment plant situated in Bota, Perak. Meanwhile for sample 6) Tronoh, 7) Siputeh and 8) Batu Gajah the source would be from Sultan Idris Shah II (SIS II) water treatment plant. A simplified schematic diagram of water supply from SIS II, Parit is shown in Figure 8. While for sample 9) Ipoh the water sources from the Ulu Kinta water treatment plant. According PWB, the capacity and production of treated water for each plant differs. The values of each are also shown in Table 8.



Source: PWB

Figure 8: Schematic diagram of water supply from SIS water treatment plant

Table 8: Data on water treatment plant, the capacity and production rate

Water Treatment Plant	Sample locations	Plant Capacity (mld)	Plant Production Rate (mld)
Kg. Senin, Bota	1,2,3,4 and 5	34.13	20.60
SIS (II), Parit	6,7 and 8	272.22	220.28
Ulu Kinta	9	136.38	88.66

Source: PWB

3.3.3 Sample Collection, Preservation and Storage of Samples

Specific location of water sampling is shown in Appendix IIIA. The samples were stored in 500mL polyethylene bottles. The tap water left to run for 5 minutes. Then, the sample was collected in the bottle. Once the samples were taken from the specified locations, it is required to be preserved so that it could be used for longer period of time. Preservation is needed to stabilize analyte in the samples. According to Lesley (2009) in *Practices for Collection and Handling of Drinking Water Samples Version2.0*, preservation can be done in two ways for drinking water samples that are pH control and refrigeration. In this study, the preservation were done by adding few drops of concentrated HNO_3 to set the pH of the sample to be less than 2. The samples were then kept in refrigerator and temperature was set in the range of 4^0C.

3.3.4 On-site and laboratory analysis of the samples

The research work would be focusing on measurement of other heavy metals content that are not determined in the previous study such as Cd and Cr. Meanwhile, repetition of analysis will be done to Pb, As and Hg that received errors during the work. Due to the resampling of the samples, common on-site analysis such as analysis of the pH and conductivity were also carried out at the site of the sample collection. These were done using the portable pH and conductivity manufactured by HACH. Temperature compensation method has been used to calculate the conductivity at 25^oC. The procedures were closely followed as suggested by Barron and Ashton (n.d) and McPherson (1997).

Other parameters such as turbidity, total suspended solid (TSS) and total dissolved solid were also measured. Turbidity was measured using DR4000 Spectrophotometer. TSS and TDS were determined through experimental work. For determination of TSS, Whatmann Microfibre Filter GF/C was used to filter the sample. It was placed in aluminium dish. With the assistance of vacuum pump and filtration apparatus, 50 mL of the sample was filtered. The filter paper was then dried in the muffle oven at 103^{o}C for one hour. Meanwhile for TDS, 30 mL of the filtrate obtained from the filtration of the sample was placed in a crucible and dried in the muffle oven at the same temperature for overnight. Both of the dish and crucible were place in the electronic dry cabinet for cooling. The weigh was measured when the temperature stabilized.

As soon as the samples were preserved and pass the holding times of 24 hours, the samples can be transported to the laboratory for heavy metal analysis using FAAS in UTP and to external laboratory that is Edtech Associates Sdn. Bhd. Different methods were adopted for each of the metals. These methods are approved standard methods by American Public Health Association (APHA). For analysis of Cd, Cr and Pb, direct extraction/air-acetylene flame method was used. Meanwhile manual hydride generation AAS method was used in determination of As in the samples. Cold-vapor AAS method is applied in determination of Hg and for Sn direct air-acetylene flame method was used.

3.4 Project Planning and Execution

The progress of the project was closely guided by the chart as shown in Table 9 and Table 10. This is to ensure that key milestones are achieved accordingly and the activities are properly carried out each week. All the key milestones were carried out and completed successfully. Measurement of pH, conductivity, turbidity, TSS and TDS are completed. The results and analysis of the data are thoroughly done in Chapter 4. The finalized results for metals concentration is the samples were reported on time by the external analytical laboratory and the analysis is also discussed in Chapter 4. Based on the Gantt chart, all activities were completed in week 7 of FYP II semester. Activities such as resampling of the water samples are not carried out as the amount of samples was sufficient for the experimental works.

Table 9: FYP I Gantt chart

No.	**Detail/Week**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	Selection of Project Topic	🟩	🟩												
	Preliminary Research Work														
	Finding literature review		🟩	🟩	🟩	🟩	🟩								
	Requisition of chemicals and apparatus					🟩	🟩								
	Search for external laboratory with ICP-MS				🟩	🟩	🟩								
	Determination of Sampling location							🟩	🟩						
2	**Extended Proposal**														
	Preparation for extended proposal				🟩	🟩	🟩								
	Submission of Extended Proposal							●							
3	**Proposal Defence**														
	Preparation for proposal defence							🟩	🟩						
	Proposal Defence presentation								●	●					
4	**Project work continues:**														
	Samples collection									🟩	🟩				
	Transportation of sample to outside laboratory											🟩			
5	**Interim report**														
	Preparation for Darft Interim Report											🟩	🟩		
	Submission of Draft Interim Report													●	
	Correction of Interim Report													🟩	
	Final interim report submission														●

● **Key milestones** 🟩 **Progress**

Table 10: FYP II Gantt chart

No.	Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	**Project work continues**														
	Preparation of samples	🟩	🟩												
	Transporting samples			🟩	🟩										
	Analysis works			🟩	🟩										
	Result collection			🟩	🟩										
2	**Progress Report**														
	Preparation for progress report				🟩	🟩	🟩								
	Submission of progress report							●							
3	**Project work continues**														
	Resampling (if necessary)							🟩	🟩						
	Sample analysis								🟩	🟩					
4	**Pre-SEDEX**										●				
5	**Submission of Draft Report**											●			
6	**Submission of Dissertation (Soft Bound)**												●		
7	**Submission of Technical Paper**												●		
8	**Oral Presentation**													●	
9	**Submission of Project Dissertation (Hard Bound)**														●

● **Key milestones** 🟩 **Progress**

CHAPTER 4

RESULTS AND DISCUSSION

This section would reveal preliminary results obtained throughout the study. The findings would then be elaborated in the discussion subsection. Results were obtained from annual water analysis done by PWB, pH and conductivity analysis during on-site sampling and trial analysis of samples using FAAS.

4.1 Results

4.1.1 Annual treated water analysis

Visit was done to the PWB and met with the person in charge of water supply for the whole state of Perak. The following data in Table 11 was obtained during the visit. It is taken from the laboratory report done by Edtech Associates Sdn. Bhd. for Metropolitan Utilities Corporation Sdn. Bhd. that managed Ulu Kinta and SIS II on behalf of PWB. From the report obtained, thorough analysis was done to treated water samples from both of the plants. This includes pH, turbidity, total hardness, concentration of total dissolved solid (TDS) and chemical oxygen demand (COD). Other than that, analysis of metal contents was also carried out such Cd, Cu, Zn and others. For comparison with previous work of Siti Hajar and Rahmanian (2012) only parameters that were studied in the work was presented in the Table 11.

Table 11: Results of PWB annual analysis (PWB, 2013)

Parameters	Water Treatment Plant	
	Ulu Kinta	SIS II
pH	7.30	8.1
Turbidity, NTU	0.85	0.80
Total Dissolved Solid, mg/L	55	63
Copper (Cu), mg/L	< 0.01	< 0.01
Magnesium (Mg), mg/L	0.55	0.43
Zinc (Zn), mg/L	<0.01	<0.01
Iron (Fe), mg/L	0.04	0.04

4.1.2 Analysis of pH

The following Table shows the pH readings taken during sampling of drinking water according to their locations. It was an on-site analysis for all the 10 samples. The same sample collection would be repeated to have the average readings of pH. There are three sets of sample collections. Data in Table 12 shows the averaging pH. The raw data of pH measurement taken during sampling is shown in Appendix II A.

Table 12: Data on pH

Location	**Temp (^oC)**	**Average pH**
UTP	20	6.92
Taman Maju (TM)	20	6.70
Bandar Universiti (BU)	20	7.39
Bandar Seri Iskandar (BSI)	20	7.12
Siputeh (SIP)	20	7.73
Tronoh (TRO)	20	6.91
Batu Gajah (BG)	20	7.37
Ipoh	20	8.67
Bottled Mineral Water (MW)	20	7.40
Water Dispenser Machine (RO)	20	6.86

4.1.3 Conductivity Analysis

On-site analysis is inclusive the measurement of conductivity of the samples. Due to the effect of temperature in measuring conductivity, samples were measured at 2 different temperatures. Conductivity at standard temperature, 25^oC was calculated using temperature compensation method that will be discussed in subsection 4.2.3.

Table 13 stipulated the conductivity at 25^{o}C while the raw data of conductivity measurement is shown in Appendix II B.

Table 13: Data on conductivity measured

Location	Temp. (^{o}C)	Conductivity (µS/cm)
UTP	25.0	113.3
TM	25.0	104.2
BU	25.0	124.8
BSI	25.0	113.2
TRO	25.0	95.8
SIP	25.0	117.3
BG	25.0	111.3
Ipoh	25.0	106.9
MW	25.0	392.0
RO	25.0	95.3

4.1.4 Measurement of turbidity

Table 14 exhibits the measurement of turbidity for all the samples. It is measure using turbidity program which was programmed in DR4000 Spectrophotometer, Environmental Laboratory of Chemical Engineering Department, UTP.

Table 14: Result on turbidity of samples

Location	**Turbidity (NTU)**
UTP	0
TM	2
BU	2
BSI	0
SIP	3
TRO	2
BG	4
IPOH	2
MW	1
RO	0

4.1.5 Total suspended solid (TSS)

The concentration of TSS in the samples was measured experimentally. Fresh (unpreserved) samples were used to obtain most accurate amount of solid in the samples. A vacuum pump was used along with the filter paper placed in the ceramic sample container. Filtered solid was then dried in the oven for one hour at 103°C. The sample will then be cooled in electronic dry cabinet and then the final mass was weighted. Table 15 shows the result obtained.

Table 15: Concentration of TSS

Location	Total Suspended Solid (mg/L)
UTP	2.00
TM	2.00
BU	0.00
SIP	0.00
TRO	0.00
BSI	2.00
BG	2.00
IPOH	4.00
MW	0.00
RO	0.00

4.1.6 Total dissolved solid (TDS)

Table 16 summarized the result of TDS that was gained through two methods. The first method would be through experimental work where the filtrate from filtration process was taken and dried overnight in the oven at the same temperature as the measurement of TSS. Second method is an estimation done based on the conductivity of the samples as further explained in 4.2.6.

Table 16: Concentration of TDS

Location	**Total Dissolved Solid (mg/L)**	
	Experiment	**Calculated**
UTP	18.00	74.90
TM	27.33	70.10
BU	42.00	75.00
SIP	34.00	75.00
TRO	24.00	77.70
BSI	24.00	59.72
BG	24.00	73.60
IPOH	56.00	71.30
MW	92.00	255.60
RO	30.67	63.53

4.1.7 Trial run of heavy metal content analysis using FAAS

The data in Table 17, 18 and 19 shows the result obtained from the trial run analysis on five of the samples using FAAS, Analytical Laboratory, Block 4, Chemical Engineering Department, UTP. The analysis was done first to obtain the calibration curve suing four standard solutions for each metals. Then, the samples were analyzed after each calibration curve was obtained. With the constraint of the equipment, the analysis was only done to determine the concentration of Cd, Cr and Pb.

Table 17: Concentration of Pb in samples

Sample	Concentration (ppm)	Absorbance
Standard 1	0.00	0.0001
Standard 2	4.00	0.0288
Standard 3	8.00	0.0584
Standard 4	16.00	0.1118
BU	-0.06	0.0005
UTP	-0.10	0.0002
BSI	-0.11	0.0001
IPOH	-0.11	0.0001
MW	-0.09	0.0003

Table 18: Concentration of Cd in samples

Sample	Concentration (ppm)	Absorbance
Standard 1	0.00	0
Standard 2	2.00	0.2774
Standard 3	4.00	0.4862
Standard 4	8.00	0.7395
BU	-0.66	0.0009
UTP	-0.67	-0.0001
BSI	-0.67	-0.0002
IPOH	-0.67	-0.0001
MW	-0.67	-0.0001

Table 19: Concentration of total Cr in samples

Sample	Concentration (ppm)	Absorbance
Standard 1	0.00	0.0000
Standard 2	1.00	0.0165
Standard 3	2.00	0.0330
Standard 4	4.00	0.0630
BU	-0.05	-0.0003
UTP	-0.05	-0.0003
BSI	-0.04	-0.0002
IPOH	-0.05	-0.0003

4.1.8 Heavy metal content analysis adopting APHA method

As discussed in subsection 3.3.4, a different methodology has been adopted in order to be able to detect concentration of desired metals. The results that were obtained from this analysis which were carried out at external laboratory are shown in Table 20. As most of the drinking water quality standards have reported concentration of heavy metals in the unit of mg/L, thus, the data was originally in the unit of ppb were converted to ppm, then converted to unit of mg/L. Consistent unit makes comparison easier. Cells that are highlighted in orange indicate that the concentration of the metal is actually below the concentration displayed. For example, for sample MW for As, the concentration is 0.00001 mg/L. The actual concentration is lower than that but due to limited detection limit of the equipment used to analyzed As, it could only detect up to 0.00001 mg/L which can be considered to be sufficient in determining the safe level of the drinking water.

Table 20: Heavy metals concentration for each sampling locations

Location	Concentration, mg/L					
	Cd	Cr	Pb	As	Hg	Tin
UTP	0.0005	0.0019	0.0018	0.00004	0.00002	0.007
TM	0.0002	0.0019	0.0014	0.00004	0.00002	0.0071
BU	0.0002	0.0014	0.0014	0.00002	0.00001	0.0054
BSI	0.0003	0.0019	0.0018	0.00007	0.00002	0.0054
SIP	0.0004	0.0014	0.0021	0.00004	0.00002	0.0036
TRO	0.0006	0.0024	0.0025	0.00003	0.00001	0.007
BG	0.0005	0.0024	0.0025	0.00004	0.00002	0.0036
IPOH	0.0002	0.0024	0.0028	0.00007	0.00002	0.0036
MW	0.00005	0.0005	0.0003	0.00001	0.00001	0.001
RO	0.00005	0.0005	0.0003	0.00001	0.00001	0.0012

4.2 Discussion

This section will deliberate on the results obtained in section 4.1, significant of each data and will also include explanations for each analysis that were carried out. Although the objective of this study is focusing on content of heavy metals in drinking water samples, other parameters such as pH, conductivity, turbidity, total suspended solid (TSS) and total dissolved solid (TDS) were also measured. Recollection of the samples may lead to different values obtained for each of the parameters.

4.2.1 Comparison of Findings between PWB and Previous Work

The above table shows the data of treated water sample taken at the specific water treatment plant (Ulu Kinta and SIS). The samples were taken at the specified sampling points for each plant. Analysis was done on the physical and chemical properties of the sample.

Table 21: Comparison of PWB and previous work data for location of Ipoh

Parameter	PWB	Siti Hajar & Rahmanian (2012)
	Ulu Kinta	Ipoh
pH	7.3	7.19
Turbidity, NTU	0.85	1.26
Total Dissolved Solid, mg/L	55	38.53
Copper (Cu), mg/L	< 0.01	0.001
Magnesium (Mg), mg/L	0.55	0.311
Zinc (Zn), mg/L	<0.01	0.001
Iron (Fe), mg/L	0.04	0.032

The above result is only part of the data displayed to provide comparison between the result of analysis from PWB and from previous work. As mentioned earlier in Chapter 2, the water that flowed to the premises originated from a specific water treatment plant. Therefore, the data is comparable and should be almost the same as it comes from the same source (same treatment plant). In this case, sample from Ipoh is compared to sample from Ulu Kinta as shown in Table 21 whereas for samples from Tronoh, Batu Gajah and Siputeh are compared to the SIS II plant as shown in Table 22.

Firstly the pH readings, it can be seen in Table 21 that for Ipoh it differs by 1.5% from the sample taken from Ulu Kinta. Its value is slightly lower than the other sample. Then, for samples from Tronoh, Batu Gajah and Siputeh which has the average pH values of 8.8 differs significantly from the sample from the plant that is by an increament of 8.64%. The value is a slightly higher of the recommended standard by WHO that is 8.5.

Table 22: Comparison of PWB and previous work data for location of Tronoh, Batu Gajah and Siputeh

Parameter	PWB	Siti Hajar & Rahmanian (2012)		
	SIS	Tronoh	Batu Gajah	Siputeh
pH	8.1	8.76	8.94	8.69
Turbidity, NTU	0.8	4.6	2.05	0.37
Total Dissolved Solid, mg/L	63	41.25	44.96	40.54
Copper (Cu), mg/L	< 0.01	0.001	0	0.001
Magnesium (Mg), mg/L	0.43	0.214	0.512	0.119
Zinc (Zn), mg/L	<0.01	0.001	0.002	0.002
Iron (Fe), mg/L	0.04	0.067	0.012	0.07

The difference in measured value maybe due to the effect of temperature. Mentioned in “pH of Drinking Water” by WHO which stated that pH value is raised by 0.45 if the temperature is raise by 25^{o}C. Referring to the report of both works, it is found that the analysis of PWB is done in the morning whereas the analysis is done some time in the evening. This might give an effect of temperature to the pH values obtained. Other than that, the sample taken from the plant is considered to be fresh out of the plant. On the other hand, samples taken from these areas were already travelled through pipelines and containment pond. Contamination may happen along the way such as leaching of Cu from the pipeline and corrosion of the piping system itself. Therefore, the pH value can be higher than the sample from the treatment plant.

Next is the turbidity, the most significant difference when compared is the sample from Tronoh. In fact, as mentioned by Siti Hajar and Rahmanian (2012) in their work stated that Tronoh had the highest value of turbidity. However, the value is still below 5 NTU indicating that it is still below the limit. Turbid water is result of the existence of particulate matter in the water. This matter caused light entering the water to scatter causes the appearance of the water to be cloudy (Turbidity: Description and Impacts on Water Quality, 2008). Having turbid water reduces the aesthetic value of the water. However, high turbidity value for few samples in the work is explained due to the delay in doing the analysis for turbidity. The turbidity is not measured immediately on site but after refrigeration and preservation process. Other than that, the slight difference value of turbidity may also be due to the erosion and also algae growth along the distribution system.

For the concentration of TDS for all tap water samples had mush lesser TDS as compared to the water samples taken from the plant. The concentration is expected to be almost the same or much higher. TDS is defined to be inorganic matters and small amount of organic matter that present as solution in water (WHO, 2003). Among the principal constituents of TDS are calcium, sodium, magnesium, nitrate ions and chloride. Lesser amount of TDS in the work of Siti Hajar and Rahmanian (2012) might be due to the difference method of analyzing the TDS concentration in the samples. Referring to the laboratory report provided by PWB, the analytical chemists adopted APHA (2540C) method to determine TDS. This method requires the filtered samples to be evaporated and dried at 180^{o}C (Norweco Laboratory, 1997). However, in the previous work, TDS in determined using method by WHO that suggested the indication of TDS through multiplication factor to the measured conductivity reading of the sample. Conductivity measured the electric current that produced by solid in the sample. With the presence of matters (Ca, Mg Na and others) lead to current flow in the water due to the ability of the matters to conduct electricity. Conductivity meter detects this current result to the reading of the current. It is a quick test to determine existence of minerals in the water sample (DeZuane, 1997). The author further elaborated that specific conductance is not really useful in determining TDS or total solids in water but only suitable to give an indication of presence of ions and the ability of water to carry electrical current. Thus, difference in method adopted to study the concentration of TDS in the samples could be the reason of vast difference in the TDS values.

For comparison of the analysis done PWB on the samples from Ulu Kinta and SIS plant, only metals that covered in the work of Siti Hajar is taken into account. Therefore, the metals compared are Cu, Zn, Fe and Mg. from the data obtained in Table 21, it is shown that metals contents from Ipoh is considered to be close to the samples taken from Ulu Kinta. As the water is root from the same source, it is assumed that the water is transported and supplied in good piping system and is not contaminated by any substances except for the reading of Mg. Concentration of Mg in Ipoh sample is 43.55% lower than stated in the laboratory report from PWB. As stated in comparison of other parameters, the reading should be near to the reported value. The same situation occurred to sample from Tronoh and Siputeh.

Different in analytical method may lead to the difference in reading. However, the analysis by Edtech Associates (EDTA) had been carried out using APHA 3111B which utilized AAS. At the same time, the previous work also used FAAS to determine the concentration in the samples. For other locations (Tronoh, Batu Gajah and Siputeh), both Cu and Zn had the almost the same concentration as compared to the sample from SIS treatment plant. On the other hand, analysis of Mg for Batu Gajah sample had higher concentration of metal that may be result from the different location of sampling. Suggested by EPA, high in concentration of magnesium or hardness maybe occurred due to deposits of underground minerals. It could not be considered as contamination as it is below the standard set by WHO and NDWQS.

4.2.2 Analysis of samples' pH

Measurement of pH relates to the acidity or alkalinity of the water. A sample considered to be acidic if the pH is below 7.0 Meanwhile, it is alkaline if the pH is higher than 7.0. Acidic water can lead to corrosion of metal pipes. Meanwhile, alkaline water shows improper disinfection of water. Standard set by WHO and also adopted in NDWQS recommend the optimum pH of drinking water is between 6.5-

8.5. Figure 9 shows the pH values for drinking water samples from 10 different sources. The highest pH with the value of 8.67 is sample from Ipoh which had slightly exceeded the allowable limit. Meanwhile the lowest is from Taman Maju with pH of 6.7 that is slightly above the recommended limit that is 6.5.

As discussed in 4.2.1, samples from the same water treatment plant should have almost the same pH readings. This is not shown in all of the samples where UTP and Bandar Universiti have vast difference of value but both still below the allowable standard. Next, sample from Siputeh and Tronoh that sourced from SIS II treatment plant also have large difference in pH value. For bottled mineral water, the measured pH is 7.4 which almost the same with the pH stated by the manufacturer on the labeled of the container that is 7.33. This indicates that the manufacturer did not provide any inaccurate information on the label. Furthermore, the accuracy of the pH meter used to measure the values for all samples is validated where the obtained result differs only by 1% by the actual readings.

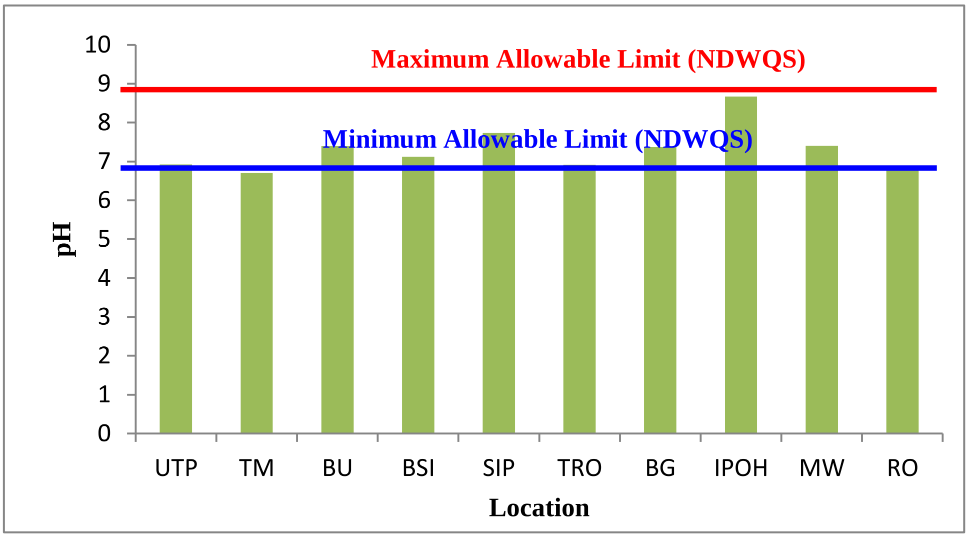


Figure 9: pH measurement for 10 water samples

As a comparison to the previous work of Siti Hajar and Rahmanian (2012) which worked with samples from the same locations, Figure 10 compares the readings pH from their work and the current work. From the figure, it can be seen that the pH measured from their work were higher than obtained in the current study. An exception is given towards samples of bottled mineral water as the sample used in their study is not known and this may not be comparable as it is manufactured by different company. The same goes to the sample from dispenser machine, as the location of the dispenser is not known. Therefore, direct comparison may not be suitable as it is may not be from the same machine. Other samples were from the same area but from different sampling location which mean, the tap where the water is taken from differ. Hence, the current study used new sampling points to recollect the samples as the samples from previous study were not preserved and had passed the holding period of two weeks.

Supposedly, the pH for samples that sourced from the same area would portray more or less the same value. However, based on Figure 10, only samples from Bandar Seri Iskandar (BSI) and dispenser machine (RO) gave almost the same readings. For BSI, it differs by 2.7% and for RO 4.5%. Different results on pH measurement may be caused by different samples that were taken from different sampling points. Equipment used to measure pH may also have an effect towards the

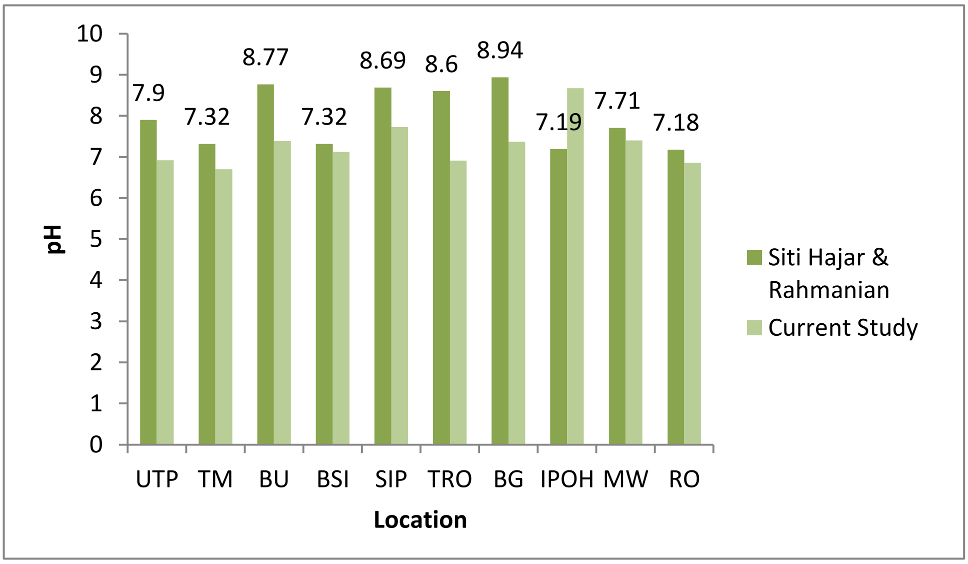


Figure 10: Comparison of pH measurement

different in data obtained. As stated in Siti Hajar and Rahmnian (2012), they have used pH meter manufactured by HANAA whilst current study used meter from HACH. This may also affect the result by the accuracy and reliability of the equipment itself.

From the results obtained above, this proves that pH can vary naturally in water according to locations. It can even affected by addition of carbon dioxide concentration in the water. Furthermore, it can decrease by 0.45 when the temperature is raised 25^{o}C higher. Thus, to ensure accuracy and consistency of measurement for each set of the samples, the meter was set to default temperature of 20^{o}C. WHO and EPA have stipulated pH to be in the secondary contaminant for drinking water as it not directly affecting consumer but has aesthetic affect. In addition, pH is a great indication of corrosiveness. The low pH could lead to the higher potential of piping and plumbing system corrosion. Leaching of metals such as Fe and Pb into water could also occur due to the acidic condition. High pH of sample such as in Ipoh may be caused by the chlorination system that caused the water to have higher alkalinity.

4.2.3 Measurement of conductivity

Conductivity of the water samples were also taken during the sample collection. It was done on-site using portable conductivity meter. Conductivity indicates the possible amount of total dissolved solids in water. Even it cannot accurately measure the exact concentration of solids, but high conductivity would reflect high content of solid in the samples. In NDWQS and guidelines from WHO have not stated the limitation of conductivity of drinking water. However, in National Water Quality Standard (NWQS), standard that covers for raw water quality had set the allowable limit for water to be fit as water supply would be below 1000 µS/cm. Based on the standard, conductivity of all samples are below this limit.

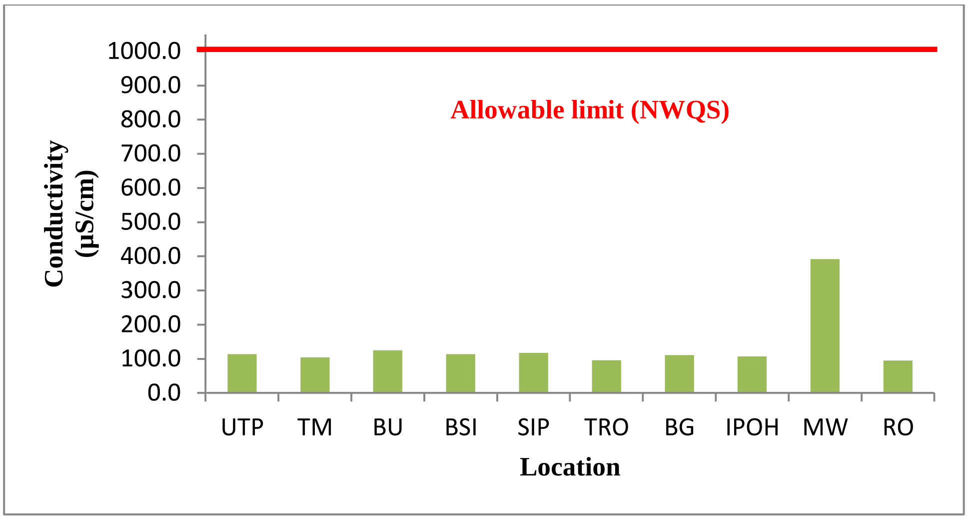


Figure 11: Conductivity measurement for 10 water samples

From Figure 11 the highest conductivity posed by sample from bottle mineral water (MW) and the lowest is from water dispenser machine (RO) that uses reverse osmosis treatment. This reflect the content of solid in mineral water which expected to be high and this is proven experimentally through determination of total dissolve solid (TDS) concentration in the samples. MW indeed shows highest content of TDS. Reverse osmosis filtration system is a system used to remove dissolved solids, turbidity, colloidal matters and others through semi-permeable membrane. Thus, dispenser machine that adopts this system would produce water with lesser amount of dissolved solids which lead to lower conductivity. This is in accordance with the result where sample from RO exhibits lowest value of conductivity.

Encountering with the same problem as mentioned in 4.2.2 where the exact location of sampling points from the previous work are not known and recollection of the samples had to be done. Due to this matter, the conductivity measured in the current study is significantly higher to be compared with the result obtained in the previous work. . Different in sampling points maybe one of the affecting factors. Conductivity is also an estimation of solid content. Hence, different sampling point may produce water samples with different solid concentration.

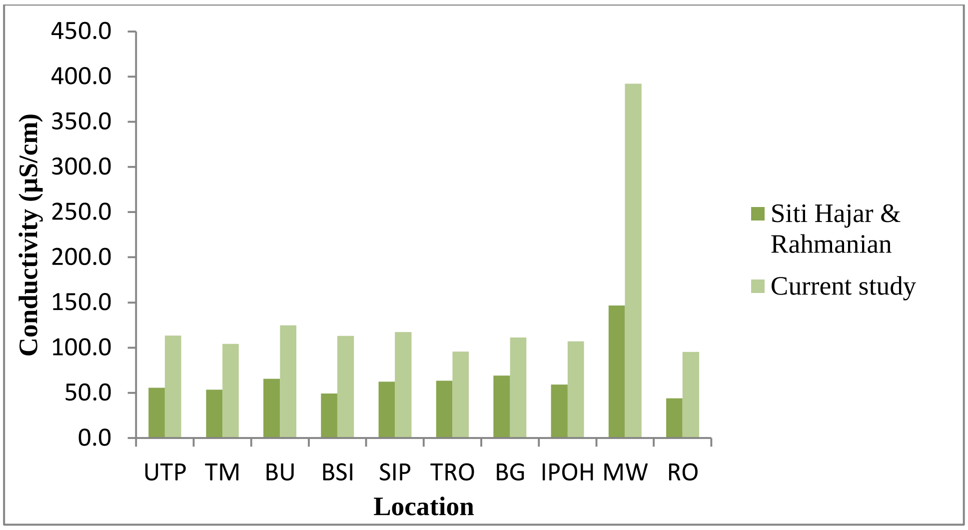


Figure 12: Comparison of conductivity measurement

From Figure 12 the effect of different sampling points can be seen. Another factor that may affect the readings is temperature at time which the measurement is taken. Temperature affects the conductivity of solution by causing lower viscosity and higher mobility of ion of the solution at higher temperature (Barron and Ashton, n.d.). Conductivity of samples which affected by these two factors may have caused different measurement of conductivity done by the two works. In the current research work, temperature compensation method had been utilized to calculate conductivity values at common reference temperature that is at 25^{o}C. Conductivity of the unpreserved samples was measured at two different temperatures (lower and higher than 25^{o}C). Then the temperature compensation formula was used to determine conductivity of the particular sample at reference temperature.

Conductivity does not have direct impact on human health. It is determine for several usage such as determination of mineralization rate (existence of minerals such as potassium, calcium and sodium) and estimating the amount of chemical reagents used to treat this water. High conductivity would lead to lower the aesthetic value of the water by giving mineral taste to the water. For water usage in the industries and agricultural activity, conductivity of water is monitored. Water with high dissolve solid (high conductivity) would cause corrosion of metal surface of equipment such as boiler. It is also applicable to home equipment such as water heater system and faucets. Food-plant and habitat-forming plant species are also eliminated by excessive conductivity.

4.2.4 Measurement of turbidity

Turbidity is defined by EPA as cloudiness of the water. It is also related to the content of diseases causing organisms in water that may be come from soil runoff. This parameter is listed to be one of the primary contaminants in drinking water. With the limit of 5 NTU set by NDWQS and WHO, consumers would be able to notice the water turbidity that is unfit to be drink when it is exceeding 5 NTU. Figure 13 shows the results of turbidity values obtained from all 10 samples. All samples were found to be within the allowable limit. Sample from Batu Gajah (BG) with the highest turbidity value of 4 NTU and the lowest from UTP, BSI and RO with 0 NTU. In the sanitation health guideline from WHO which stated that effective chlorination system would give turbidity of water less than 0.85 NTU. This shows water from UTP and BSI were properly chlorinated. Water from reverse osmosis dispenser machine is also expected to have low turbidity value due to the filtration system that is possessed to ensure efficient removal of undesired solids and organisms that may cause turbid water.

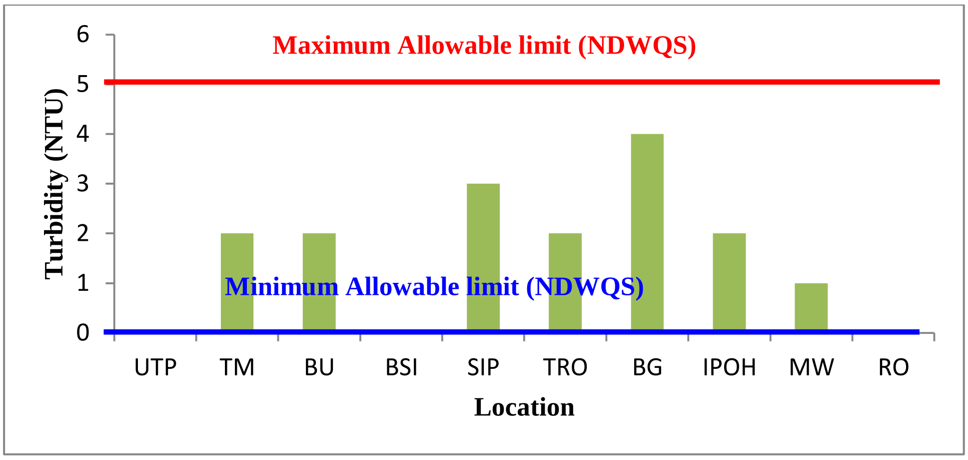


Figure 13: Turbidity

As for samples from BG, the visible appearance of the water to be brownish in colour (Appendix II C) may have led to a higher turbidity value. The colorization of the sample may not cause turbid water but may have affected the reading of the equipment.

Comparison is also made between the turbidity value obtained in the current study and previous work. Undoubtedly the results shows significant different. In the previous work, the sample that had the highest turbidity was sample from Tronoh and the lowest is from bottled mineral water (Siti Hajar and Rahmanian, 2012). Values from other locations are not the in the same range and trend. Again, this may be caused due to the different samples used in analysis. As explained by the author, the turbidity measurement was not taken fresh and this may have affected the result.

4.2.5 Concentration of TSS

TSS has not being stated in any standards such as in NDWQS, EPA and in WHO guideline. However, the limitation of TSS is stipulated in the NWQS which is 25 mg/L for Classes I water and 50 mg/L for Classes IIA and IIB water. Definition of the water classes is summarized in APPENDIX IIIA. Figure 14 shows the amount of suspended solid in the water samples according to locations.

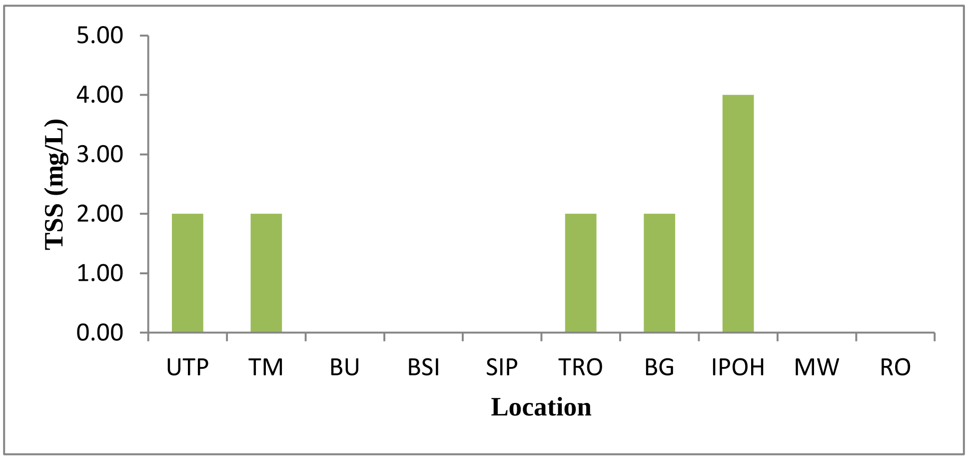


Figure 14: Concentration of TSS

Five of the samples are found to be zero from suspended solids that are BU, BSI, SIP, MW and RO as shown in Figure 14. The highest concentration of TSS with 4 mg/L is sample from Ipoh. The appearance of the sample does not exhibits any suspended solid but after the TSS was done experimentally, the sample shows having highest concentration of TSS. The existing of high concentration of TSS in water can be seen from the sedimentation of solid at the bottom of the water container. Nevertheless, due to the very low amount of TSS, sedimentation of solid is not seen in any of the samples.

4.2.6 Concentration of TDS

TDS is interrelated with conductivity of the sample. TDS can be estimated using correlation factors that can be multiply with the measured conductivity. This method is used in the work of Siti Hajar and Rahmanian in determination of TDS concentration. They have adopted correlation factor of 6.5 that is then multiplied with the conductivity in the unit of S/cm. Due to the source of the correlation factor used by the authors cannot be determine, in the current study, the method of estimating TDS is adopted from American Water Works Association (2002) by multiplying the conductivity in unit of µS/cm by constant ranging between 1.2-1.8. Average of the constant that is 1.5 is used. Experimental procedures were also carried out in determination of TDS. The result was then compared in Figure 15.

The maximum allowable limit of concentration of TDS in drinking water is set to be 500 mg/L. Figure 15 shows that all the samples are below the limit. The highest amount of TDS is found to be in bottled mineral water. Both experimentally and estimated value of TDS indicated to be the highest value. The sample that has the lowest concentration of TDS is UTP (experimental) and RO (calculated). Data obtained through calculation is higher than the experimental work. This is due to the value calculated is just a rough estimation of solid content in the samples (DeZuane, 1997). Therefore, concentration of TDS obtained through experimental work would be considered having better reliability. It is proven by comparing the TDS value written on the label of the bottled mineral water to the value obtained through experiment. Experimentally, the TDS is 92 mg/L while on the label stated 126 mg/L.

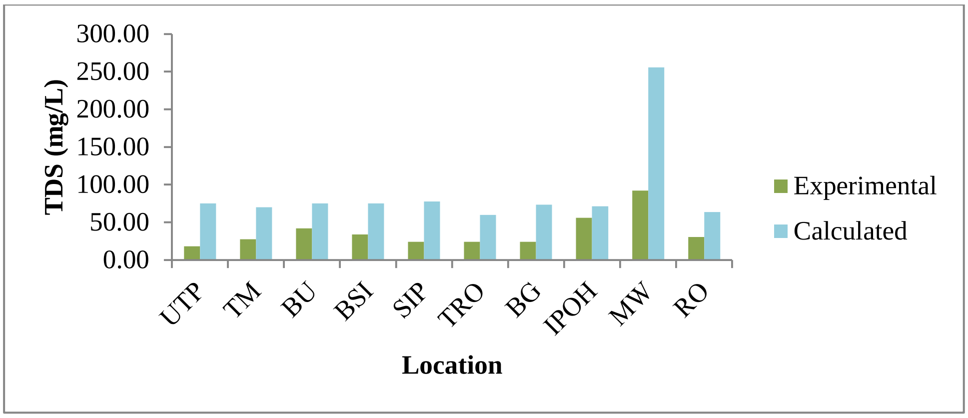


Figure 15: Concentration of TDS

This gives percentage of difference of 27%. Losses of dissolved solids throughout the procedures may lead to the lower amount of solid obtained. When comparison is made between the labeled TDS to the estimated TDS value, the difference is 102.9% which is more than double of the labeled value. Thus, the values obtained through experimental work are more acceptable and accurate as compared to the estimation method. Comparison can also be done to the values of TDS obtained in the work of Siti Hajar and Rahmanian (2012) but due to the lower conductivity measured in the work, the values of estimated values of TDS would also be lower. Hence, the obtained values in the work are observably lesser as compared to the estimated TDS in the current study.

4.2.7 Trial run of heavy metal content analysis using FAAS

Five of the samples were tested using the FAAS. The analysis was done to determine concentration of Pb, Cd and Cr in the samples. The samples were from Bandar Universiti, UTP, Bandar Seri Iskandar, Ipoh and bottled mineral water. Standard solutions were prepared for the three elements prior the analysis was carried out. This is because the solution needed to be prepared fresh each time and to ensure accurate analysis. The solutions were prepared to obtain the standard calibration curve that later on would be utilized to determine the unknown metal concentration in the samples.

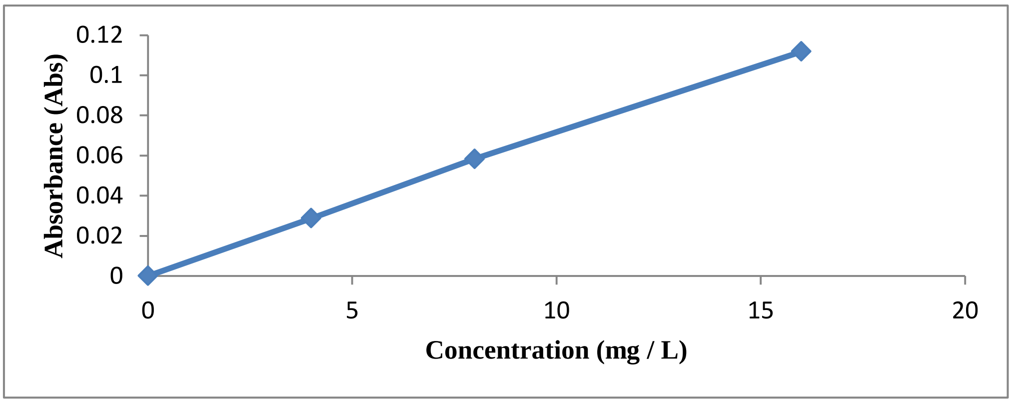


Figure 16: Standard curve for Pb

For determination of Pb in the samples, standard solution with 4, 8 and 19 mg/L were prepared in 100ml volumetric flask. The solute is an ultrapure solute of the metal in form of solution. Distilled water was used as the solvent for diluting the solution. The solutions were then run with the FAAS to obtain the standard calibration curve. As demonstrated in Figure 16, the curve was drawn based on the absorbance value of the sample. Correlation coefficient of the curve is 99.97% which shows that the curve is acceptable and can be used for the analysis. If the value is less than 97%, the standard solution needed to be re-prepared. Then, the five samples were taken to the equipment for analysis. The result of the analysis for the standards and samples is shown in Table 16. Unfortunately, the concentration of Pb in all of the samples was found to have negative values. A discussion was made with the technologist in-charge for the FAAS. The negative value of the concentration may not be due to errors. It may be due to the inability of the equipment to detect lower concentration.

The same procedures of experiment were carried out for Cd and Cr determination. For Cd, the standard solution was prepared for 2, 4 and 8 mg/L. While, standard solution of 1, 2 and 4 mg/L was prepared for Cr analysis. The standard calibration curves are shown in Figure 17 for Cd and Figure 18 for Cr.

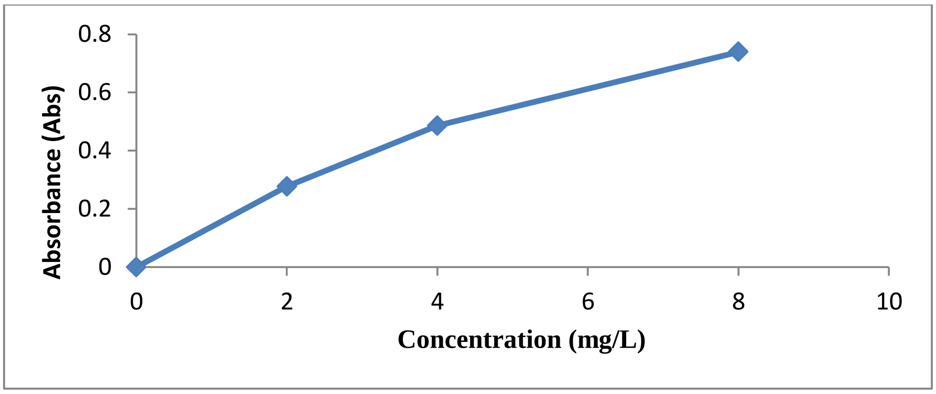


Figure 17: Standard curve for Cd

The metal content was recorded as the analysis of the 6 samples was completed. The concentration of Cd and Cr were also found to be negative value. This indicates that the equipment is incapable of detecting low concentration of metal as expected in drinking water samples. Therefore, other equipment such as GFAAS, ICP-OES and ICP-MS are the equipment that is expected to able to detect the metal concentration.

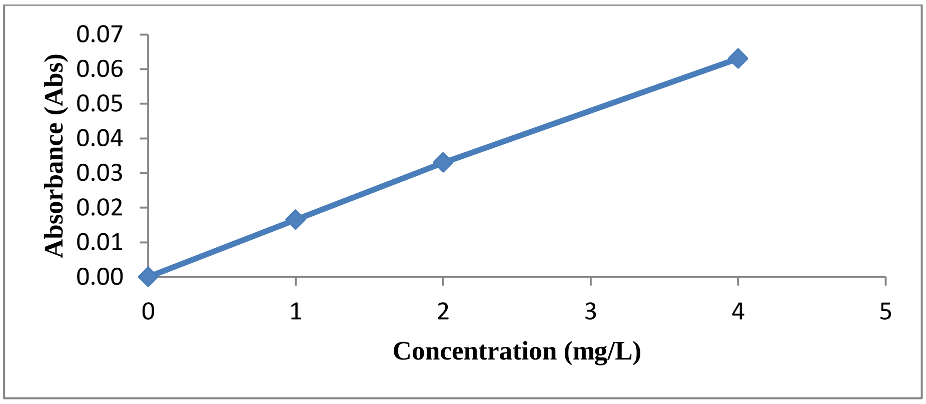


Figure 18: Standard curve for Cr

4.2.8 Heavy metals content analysis adopting APHA method

Based on the results discussed in 4.2.7 on inability of direct flame air-acetylene atomic absorption method used to detect Cd, Cr and Pb is due to the detection limit of the method. Concentration of these metals in the samples is expected to be in ppb unit. Therefore, the method used to analyze Cd, Cr and Pb is considered unsuccessful. The same method was not used to analyze content of As, Hg and Tin is due to insufficient compartment of the spectrophotometer itself. As AAS used radiation wavelength to determine the content of the samples, the light source (bulb) would need to be change according to the content that is desired to be analyzed. Due to the unavailability of suitable light sources for As, Hg and Tin, train run was not carried out.

After few discussions and surveys were done, the samples were sent to Edtech Associates Sdn. Bhd in Penang, a private analytical laboratory to analyze all the heavy metals elements in the samples. The laboratory is also handling water samples from PWB for monthly analysis and reporting on quality of treated water. As mentioned in 3.3.4 the method used to quantify the concentration of the elements is based on varies spectrometric method by APHA. By adopting the methods, the concentration of all the metals was successfully determined as shown in Table 20. For each of the element, the graph of the element's concentration and sourced of the samples were plotted in Figure 19 for Cd, Figure 20 for Cr, Figure 21 for Pb, Figure 22 for As and Figure 23 for Hg.

Based on Figure 19, it shows that concentration of Cd in all the drinking water samples are far below the maximum allowable limit set by local standard that is taken from Drinking Water Quality Division, Ministry of Health, which the standard is known to be as NDWQS. The concentration limit of Cd to be treated

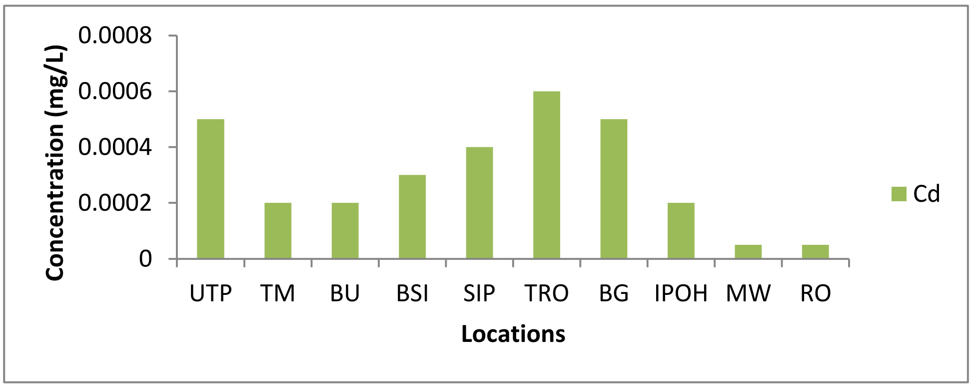


Figure 19: Cd concentration in each sample

water would be 0.003 mg/L. It is in line with the guidelines set by WHO in Geneva 1993. Sample from Tronoh (TRO) is having the highest concentration of Cd that is 0.6 ppb or 0.0006 mg/L. The lowest concentration of Cd was found to be 0.05 ppb for both mineral water (MW) and water from reverse osmosis filtering system (RO). The concentration of Cd in the samples is found to be very low that it can be presented in unit of ppb.

This metal can enters water from the environment in several ways as discussed earlier in Chapter 1. It can occur naturally in rocks and soils and enter water when there is contact with soft groundwater or surface water (Hanaa *et al*., 2000). Other than that, it may be introduced by paints, pigments, plastic stabilizers, mining and smelting operations, other industrial operations such as electroplating, fossil fuel, fertilizer and sewage sludge disposal.

The authors added that it may also enter tap water from galvanized steel pipe that is usually plated with zinc which usually has 1% of Cd. It can also source from fittings with cadmium soldering (Mona et al., 2008). High concentration of Cd in tap water is usually caused by corrosion of the galvanized steel pipe or leaching of leachate from landfill (Hanaa *et al*., 2000). The concentration of Cd in water sample from Tronoh that is found to be the highest when compared to samples from other locations is maybe from corrosion of galvanized steel pipe that is used for piping of water distribution in the area. It is not considered to be from other sources because the location of sampling (residential area) is not located near to any industrial zones or waste disposal areas. However, since the concentration did not exceed the standard limitation, risk of contamination is considered to be none. Mineral water and RO water were found to have the lowest concentration of Cd, this indicates that the water has gone through thorough processes that caused the mineral content in the water to be minimum.

Next for concentration of chromium (Cr) that has been plotted in Figure 20 portrays that the highest concentration of Cr was found the same with the value of 0.0024 mg/L or 2.4 ppb in samples from Tronoh, Batu Gajah and Ipoh. Again sample from bottled mineral water and reverse osmosis show the lowest content of Cr. Even with the highest concentration to be 0.0024 mg/L, it has not exceeded the guideline from WHO that is 0.05 mg/L (Siti Hajar and Rahmanian, 2012), concentration for public health goal from EPA that is 0.1 mg/L (EPA, 2013) and 0.05 mg/L from NDQWS. The concentration is found to be 52% lower than the local standard.

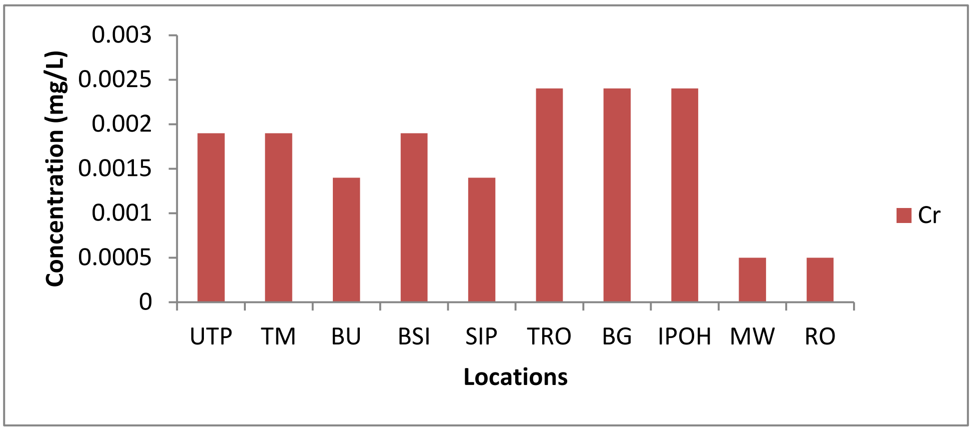


Figure 20: Cr concentration in each sample

Source of Cr in drinking water may come from waste discharge from industries such as steel and pulp mills (EPA, 2013). It is also can be found from erosion of natural deposits from the surrounding area. Usage of chromium in many of other industries has added up to the high possibilities of contamination from waste of metal alloys and paint producing industries (Hanaa *et al.*, 2000). The source of tap water from Tronoh which is located in the township, from Batu Gajah located in residential areas, and Ipoh also from residential areas that are not located near to any industrial activities. Therefore, the contamination of Cr which mostly expected to be from industrial waste is not applicable. This proved that even sample with the highest concentration of Cr is still managed to fall far below the recommended concentration.

Figure 21 is a plot of concentration (mg/L) Pb that is quantified in the water samples versus the location where the samples were taken. The graph shows that the highest concentration of Pb was found in drinking water from Ipoh with the value of 0.0028 mg/L. This value does not exceed the recommended concentration of Pb in drinking water by WHO (0.01 mg/L), maximum allowable contamination level of Pb by EPA (0.015 mg/L) and NDWQS (0.01 mg/L). Concentration of Pb in bottled mineral water and reverse osmosis water is found to have the lowest concentration of 0.0003 mg/L. Based on the highest concentration of Pb in Ipoh drinking water sample, it can be concluded that all the water is safe to be drink as it falls far below the maximum allowable limit which 280% lower than the standard concentration.

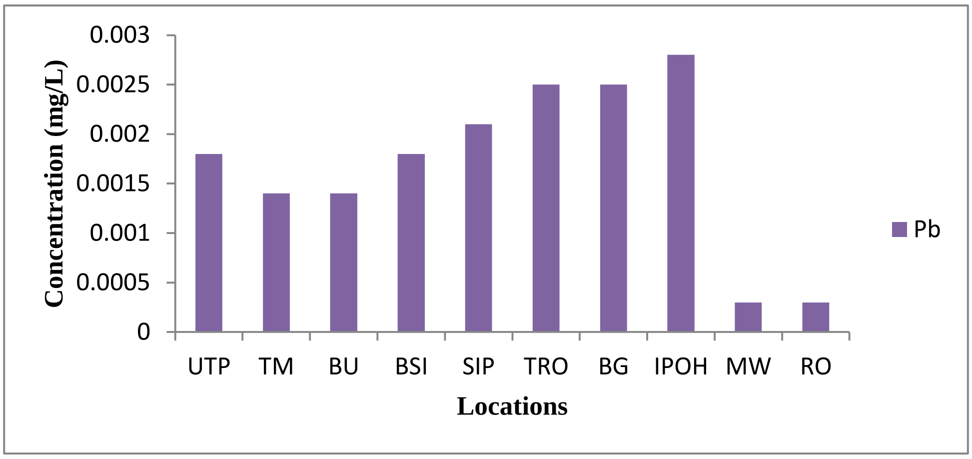


Figure 21: Pb concentration in each sample

Sources of Pb can be particularly from household plumbing system that used Pb-based pipes (Hanaa *et al.*, 2000, Dissmeyer, 2000 & Morais, n.d.). It can also source from erosion of soil containing Pb. Thus, the slight different concentration of Pb in Ipoh from other locations may cause by the type of piping used in the water distribution system and also content of the surrounding soil which may have higher amount of Pb that may leached into the water. Lead can enter human body through inhalation, ingestion and through drinking water. Lead is not essential to human therefore a small amount of lead in the system could give effects to health especially to children. Although most of the consumed Pb can be removed through urination but it could easily accumulate in the body. Excessive concentration of Pb can caused death and permanent damage to central nervous system, brain and kidneys (Hanaa *et al.*, 2000). The most common problems that are caused by high concentration of Pb would be memory and hearing problems, high blood pressure, muscle and joints pain and some others. It could also interfere with child's growth and relates to anti-social and crime behavior in children as cited from US G.A.O, General Accounting Office report (2000) by the authors. Hence, based on the result obtained it is proven that the water consumed by the community is safe from contamination of Pb.

Figure 22 is the comparison of As concentration from 10 sources of drinking water. the maximum concentration for As, 0.01 mg/L that is set by WHO, USEPA and NDQWS which would not risk health. From the figure, it is shown that the highest amount of As was found in two samples that are from Bandar Seri Iskandar and Ipoh which is 0.00007 mg/L. Even with the highest value of As from all samples, the concentration is not exceeding the maximum allowable limit set by the bodies. In Figure 22, the value plotted for MW and RO is 0.00001 mg/L for the ease of result comparison. In the result obtained from the analysis, concentration of As in the two samples were actually lower than 0.00001 mg/L. Exact concentration cannot be quantify due to the equipment limitation. Mineral water and RO possess the lowest concentration of this metal which the water is further processed through filtration system that removed most of the minerals in the water .

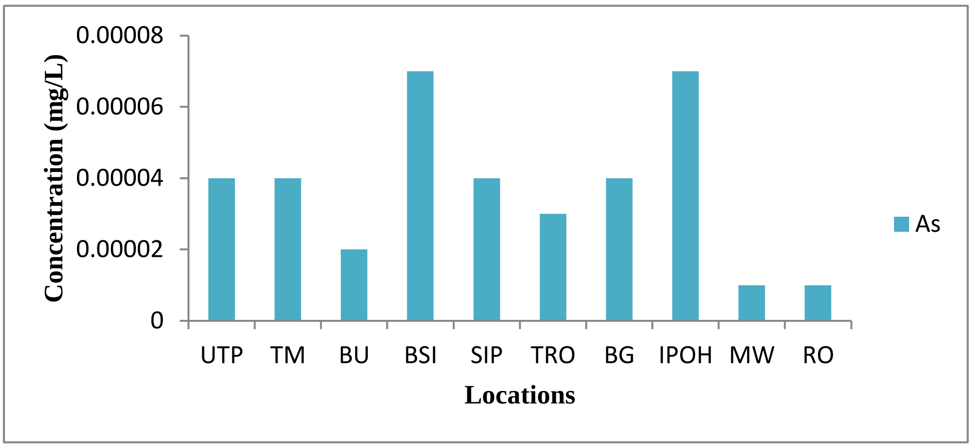


Figure 22: As concentration in each sample

Erosion of natural deposits, runoff from orchards which arsenic maybe from used of fertilizers and herbicide, manufacturing of semi-conductor and waste runoff from glass and electronics production plant are the possible sources of high arsenic in drinking water. Based on the geographical location of the specific area from which the samples taken (Bandar Seri Iskandar and Ipoh), both areas are residential areas. However, for Ipoh, the housing area is located near to Kinta small-medium industrial area which may be causing the higher concentration of As in sample from Ipoh as comparison to other samples. High As in water may also cause deposition of the element from the soil of the area. It is known that Perak is the land of tin-mining. In Malaysia, this area is found to be rich with minerals such as As (Yusof *et al.*, 2001). The authors added that rivers passing mining areas could carry with them toxic compounds such as heavy metals and As. Thus, this could be the source of having higher concentration of As in the samples. This would also explain the low concentration of As in mineral water and water from dispenser machine which subject to further purification that limit the concentration of minerals in water produced from their systems.

Analysis of Hg in drinking water samples were also carried out. Figure 23 discusses the results obtained from the analysis. Based on the figure, 6 samples were found to have the highest concentration which is samples from UTP, Taman Maju (TM), Bandar Seri Iskandar (BSI), Siputeh (SIP), Batu Gajah (BG) and Ipoh. The concentration is extremely lower than the maximum allowable concentration which is 0.001 mg/L (WHO and NDQWS) and 0.002 mg/L from USEPA. Thus, the water

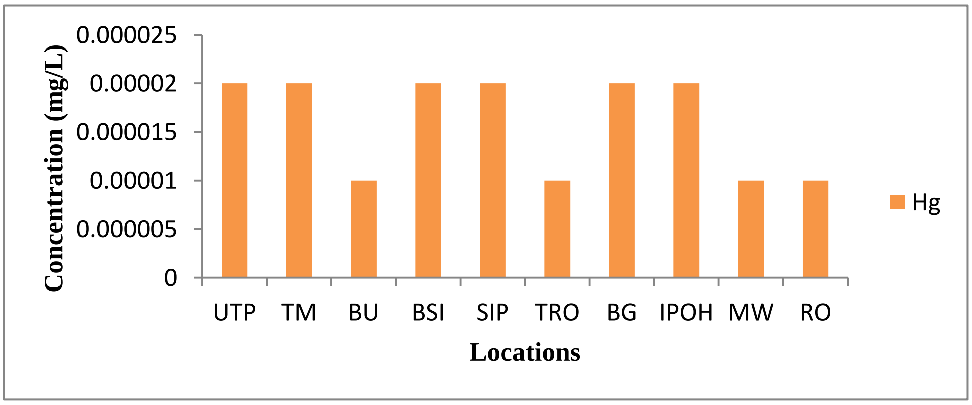


Figure 23: Hg concentration in each sample

is considered to not contaminated with Hg due to the amount of Hg in the water is not exceeding the maximum concentration set by NDWQS, WHO and USEPA. Concentration of Hg in bottled mineral water and RO water should be lower is analyzed to be lower than 0.00001 mg/L. However, exact concentration of Hg cannot be determined due to limitation of detection limit of the method used to analyze Hg in the samples. Thus, in the figure the value is plotted to be 0.00001 mg/L for the purpose of comparison.

Suggested by USEPA, high Hg concentration in drinking water can source from erosion of natural deposits, improper discharge of waste from refineries and factories and runoff from landfills and crops. Although the concentration of this element in all samples does not exceeded the limit but the potential causes of high concentration from the six locations mentioned above can be estimated. For locations such as UTP, Taman Maju, Bandar Seri Iskandar, Siputeh and Batu Gajah are not located near to any known refineries, factories, landfills or croplands. Thus, the possibility of the Hg to come from these sources is eliminated. Left with the potential erosion from the soils or rocks which the water flows and Hg maybe naturally exist can leach into the water. Meanwhile for Ipoh which located near to a small industrial area which can also be the source of Hg despite from the possible source of contamination from erosion of natural deposits.

Figure 24 shows the comparison of Sn concentration in all the samples. There are no maximum concentration of Sn set by WHO, USEPA and NDWQS. According to USEPA, Sn is not considered to be primary or secondary pollutants for drinking

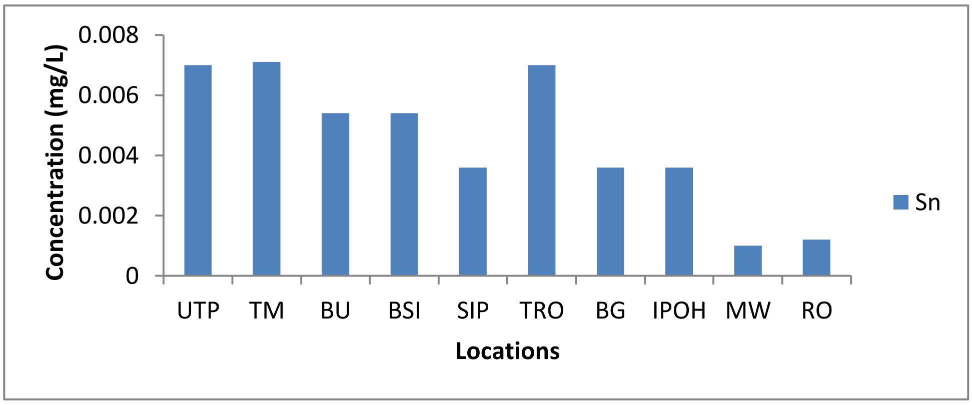


Figure 24: Sn concentration in each sample

water. Meanwhile, WHO explains that drinking water is not a crucial source of tin as compared to canned food that is more common to be contaminated by tin. It is also explained that inorganic tin compounds are not easily absorbed and pose very low risk to human health as it is easily excreted in the urine. However, the analysis of Sn in the samples is carried out due to the fact that these locations are near or on ex-tin mining area where Sn compounds can easily enters the sources of drinking water.

Result from the analysis is compared to a standard that is used to determine the suitability of water to be used as source of water supply. It is reported in Environmental Quality Report for the year of 2009 by Department of Environment, Malaysia as National Water Quality Standard (NWQS) for Malaysia. This standard set limit for parameter such as TSS, TDS and heavy metals concentration for different classes of water (APPENDIX III). In this standard, Sn concentration should be absent for water classes I and IIA and IIB. Meanwhile for class III water, the maximum allowable concentration for Sn is 0.004 mg/L. Based on this allowable limit, it is found that five of the samples have exceeded this value. The samples are UTP, TM, BU, BSI and TRO. The highest concentration of Sn is found in three samples (UTP, TM and TRO) with the value of 0.007 mg/L. As mentioned before, the value used to compare the result of the analysis is for determination of water supply suitability. Thus, for treated water, the concentration of Sn should be much lower.

Metal mining is found to be the second largest source of metal contamination in soil (Ashraf, Maah and Yusoff, 2011). This includes metals such as zinc (Zn), copper (Cu), Pb and Sn. Based on the trend of the location which the Sn concentration is found to be high, the areas are found to be the ex-tin mining area or near to a tin mining area. This would explain the high concentration of the element in the five samples. The metal can enters water during the treating process of the water which the treatment plant could be near or on a tin mining area. Improper lining of treatment tanks and piping may cause tin to leach from the surrounding soil. This may also occurred along the distribution system. Next, Sn can also leach from Sn-Pb solder joints (Subramanian *et al.*, 1995). Corrosion and dissolution of the joint can be the potential source of Sn, Cd, Zn, Cu and Pb leaching into the water. As mentioned earlier inorganic tin which is quantified in this study is known to have low hazard to human and animals. Despite from that, this compound can be converted into the second most toxic organic tin such as methyltin through bacterial reaction as quoted by Subramanian *et al.* (1995) from Clark *et al.* (1988). Thus, high concentration of inorganic tin can also pose high risk to health as it can be converted into organic tin that can caused neurotoxic effect to human and animals (Zongyan *et al.*, 2011).

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

Drinking water supplied to the community is supplied from several sources. Raw water from Perak River would be treated in several water treatment plants in order to achieve clean water supply for the people. Containment pond and piping system are among the facilities needed to distribute the water. It is expected that, water from the same treatment plant would produce almost the same findings. However, comparison between PWB and previous work reflect the otherwise. For some parameters such as pH and metal concentration differs even the samples are rooted from the same plant. Comparison also made between samples from the same location but with different sampling points. Results show most of the parameters were not in the same trend except for sample MW which the trend of the conductivity exhibits the highest in the both previous study and current study. It can be concluded that, locations of the sampling give a significant affect towards the result of drinking water quality analysis. Direct comparison of data from each of the studies may not be appropriate as it indeed would contradict with one and another. Effect of different equipment and method used by operator may also lead to differences in results obtained.

Experimental works were done on measuring pH, conductivity, turbidity, TSS and TDS. Based on the findings, pH of samples from Ipoh has exceeded the NDQWS standards. Temperature compensation method has been utilized for calculating the conductivity of the samples at reference temperature. This is done to create consistency in the value of measured conductivity as it can be affected by change in temperature. Conductivity of all samples have not exceeded the limit for conductivity of 1000µS/cm. Turbidity of drinking water samples were found to be below the limit of 5 NTU set by NDWQS. Concentration of TSS was below the maximum allowable limit of 25 mg/L for Classes I and Classes IIA of water that is suitable for water supply as stipulated in NWQS. In this study, TDS was determined using two methods that were through experimental work and estimation method. From both results obtained, concentration of TDS in all samples was found to be below 500 mg/L. For analysis of heavy metals in the samples, concentration of all analyzed metals except for Sn were found to be below the maximum allowable concentration set by NDWQS, WHO and USEPA. Sn was found to be high in samples from five locations which has the potential of contamination from location itself which is on or near to an ex-tin mining area and leaching of Sn from usage of Sn-Pb based solder of piping fittings and joints. Based on the analysis, the water from the ten sources is considered to be safe as drinking water as all the analyzed parameters were within standards set by the Malaysian Ministry of Health, WHO and USEPA regardless of Sn that is not considered as pollutant for drinking water by these bodies.

In the nutshell, this research can determine the safe and quality level of the water that has been supplied to the community. The outcome from this study could benefit the people of the particular research areas, the Health Department of Perak and assist PWB in monitoring the quality of water supply. The project methodology has been improvised along the way in order to ensure reliable and accurate data is obtained. Overall, with the completion of experimental work and the data analysis, the objectives of project are achieved successfully.

5.2 RECOMMENDATION

The study which solely relies on analysis of parameters that can affect water quality through experimental work and analytical equipment can be improved by using standardized methods of analysis. This can be done by using the same procedures and equipment. Furthermore, the quality of water from the locations have to be monitored for a longer period of time such as for one year in order to have a series of data or trends so that the study would be more firm and reliable. Standardization of the sampling locations would also help in making the data obtained comparable. Besides, basis of selection for sampling locations has to be stated clearly as this could give strong credibility to the study. As for this study which is a continuation of a study carried out previously, the sampling locations were chosen based on the same locations that had been decided in the previous study. Other than that, future studies can be made on determination of organic tin in drinking water which would have higher risk to human than inorganic tin. Relation can then be made with the high concentration of inorganic Sn in the samples to the concentration of organic Sn that maybe result to the bacterial action. Study can also be carried out in assessing concentration of Sn in human body through analysis of urine or blood paired with health impact assessment to a population in certain locations that may have been affected by high concentration of Sn in drinking water.

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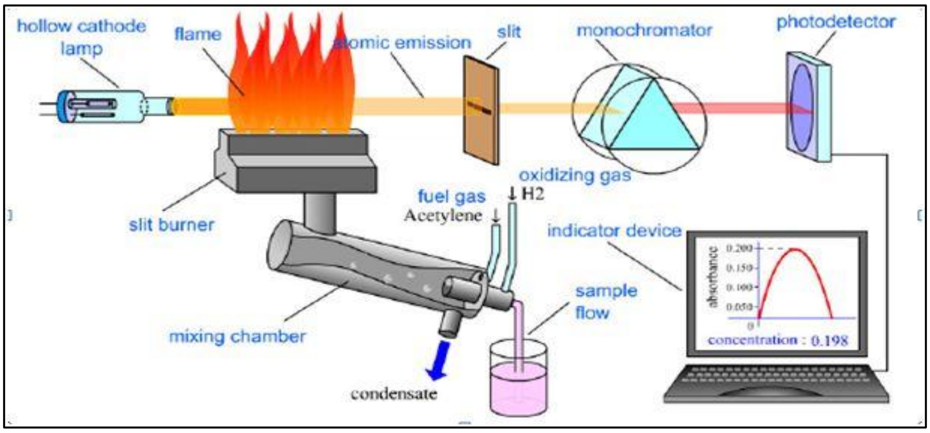
APPENDIX I

A. Basic instrumental component diagram for FAAS

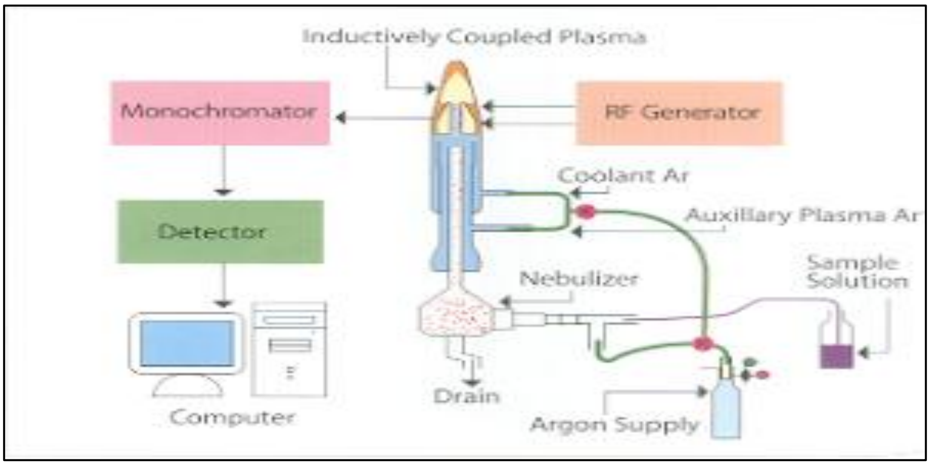


Source: http://oscartigasembilan03.blogspot.com/2012/10/atomic-absorption-spectrophotometer-aas.html

B. Perkin Elmer: AAnalyst 800 AAS equipment

Source: www.perkinelmer.de

C. Basic instrumental component for ICP-AES/OES

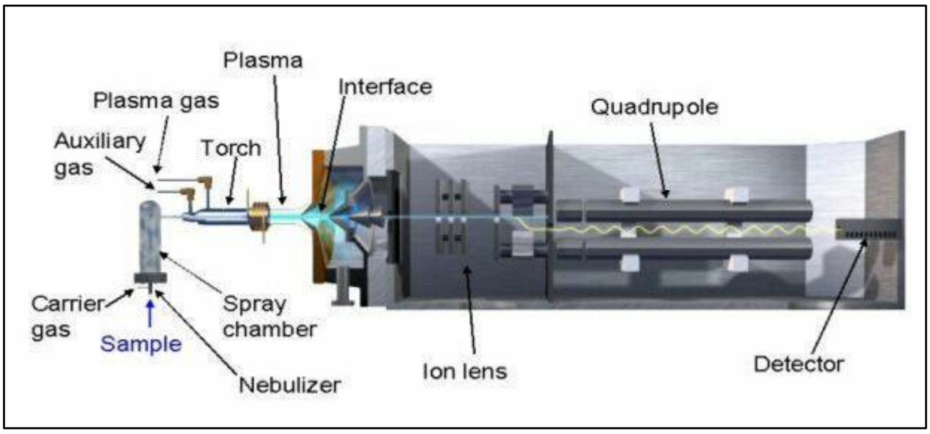


Source: http://www.rsic.iitb.ac.in/Icp-Aes.html

D. Perkin Elmer: Optima 5300V ICP-OES equipment

Source: www.perkinelmer.de

E. Basic instrumental component diagram for ICP-MS



Source: Washington University in St. Louis, http://eecelabs.seas.wustl.edu/ICP-MS.aspx

F. Perkin Elmer: Elan 9000 ICP-MS equipment

Source: www.perkinelmer.de

APPENDIX II

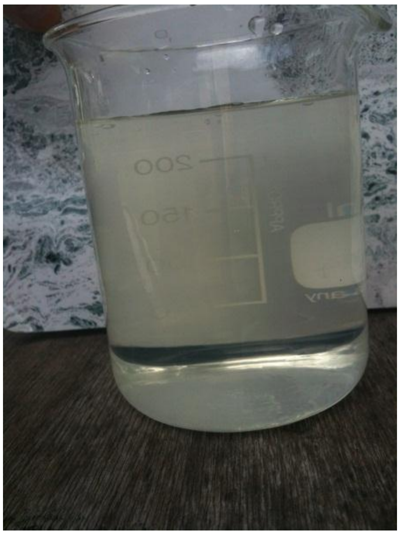
A. Raw data of pH measurement

Sample No.	Location	Date	Time	Temp (^oC)	pH	Average pH
1	UTP	15/05/2013 22/05/2013 29/05/2013	12:24 08:46 08:01	20	6.89 7.01 6.87	6.92
2	Taman Maju (TM)	15/05/2013 22/05/2013 29/05/2013	15:40 10:23 08:20	20	6.60 6.75 6.77	6.70
3	Bandar Universiti (BU)	15/05/2013 22/05/2013 29/05/2013	14:55 09:30 08:37	20	7.14 7.59 7.45	7.39
4	Bandar Seri Iskandar (BSI)	15/05/2013 22/05/2013 29/05/2013	15:16 10:04 08:50	20	7.26 7.03 7.07	7.12
5	Siputeh (SIP)	15/05/2013 22/05/2013 29/05/2013	13:20 11:18 09:16	20	7.63 7.80 7.75	7.73
6	Tronoh (TRO)	15/05/2013 22/05/2013 29/05/2013	12:56 10:58 09:03	20	6.82 7.01 6.90	6.91
7	Batu Gajah (BG)	15/05/2013 22/05/2013 29/05/2013	14:20 11:38 09:46	20	7.34 7.39 7.38	7.37
8	Ipoh	15/05/2013 22/05/2013 29/05/2013	09:45 12:18 10:19	20	8.61 8.70 8.69	8.67
9	Bottled Mineral Water (MW)	15/05/2013 22/05/2013 29/05/2013	16:38 16:50 13:50	20	7.44 7.40 7.38	7.40
10	Water Dispenser Machine (RO)	15/05/2013 22/05/2013 29/05/2013	09:10 15:30 08:25	20	6.80 6.88 6.89	6.86

B. Raw data of conductivity measurement

Location	Date	Temp. (^{o}C)	Conductivity (µS/cm)	Date	Temp. (^{o}C)	Conductivity (µS/cm)
UTP	29/05	24.1	113.07	31/05	31.6	114.73
TM	29/05	24.1	103.97	31/05	31.8	105.90
BU	29/05	23.5	124.53	31/05	31.5	125.97
BSI	29/05	23.5	112.97	31/05	31.3	114.17
TRO	29/05	23.6	95.70	31/05	31.2	96.40
SIP	29/05	23.6	117.10	31/05	31.4	118.33
BG	29/05	23.5	111.13	31/05	31.2	111.87
Ipoh	29/05	23.5	106.67	31/05	31.6	108.17
MW	29/05	23.3	391.00	31/05	31.4	396.00
RO	29/05	23.4	95.20	31/05	28.4	95.40

C. Colorization of sample from Batu Gajah (BG)



APPENDIX III

A. Specific locations of sampling location

Sample	Location
UTP	V4A-S1, UTP
TM	Surau Al-Amin, Taman Maju
BU	Surau Al-Ikhlas, Bandar Universiti
BSI	Surau Iskandar Bestari, Bandar Seri Iskandar
TRO	Masjid Ar-Rahmaniah, Tronoh
SIP	Surau Taman Siputeh Permai
BG	Masjid Al-Imaniah, Batu Gajah
IPOH	Lot 1885, Regat Rapat Jaya 1, Kg. Rapat Jaya, Ipoh
MW	Manufactured by Permanis Sdn. Bhd.
RO	Taman Maju

B. Classes of Water

Class	Description
I	Water supply I – would not require any treatment
IIA	Water supply II – require conventional treatment
IIB	Use for recreational with body contanct
III	Water supply III – require extensive treatment
IV	Irrigation
V	None of the above