UNIVERSITI PUTRA MALAYSIA

THE CONCENTRATION OF METALS IN DRINKING WATER OF UNIVERSITI PUTRA MALAYSIA, BINTULU CAMPUS

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THE CONCENTRATION OF METALS IN DRINKING WATER OF UNIVERSITI PUTRA MALAYSIA, BINTULU CAMPUS

By

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TABLE OF CONTENTS

Page
DEDICATION ii
ABSTRACT iii
ABSTRAK iv
ACKNOWLEDGEMENTS v
APPROVAL vi
LIST OF TABLE vii
LIST OF FIGURES viii
LIST OF ABBREVIATIONS ix

CHAPTER
1 INTRODUCTION 1-2
2 LITERATURE REVIEW
  2.1 Drinking water 3
  2.2 Water Treatment Process 4
    2.2.1 Bintulu Water Treatment Process 4
      2.2.1.1 Pulsator Clarifier Water Treatment 5-6
      2.2.1.2 Dissolve Air Flotation Water Treatment 7-8

  2.3 Drinking Water in Universiti Putra Malaysia Bintulu Campus 9-10
  2.4 Metals 10
    2.4.1 Sodium 11
    2.4.2 Calcium 12
    2.4.3 Magnesium 12-13
    2.4.4 Manganese 13-14
    2.4.5 Iron 14-15
    2.4.6 Zinc 15
    2.4.7 Lead 16-17
    2.4.8 Copper 17-18
    2.4.9 Metals Concentration Standard for Drinking Water. 19

3 METHODOLOGY
  3.1 Introduction 20
  3.2 Materials and equipments 21
    3.2.1 Sterilization of equipment 22
  3.3 Study area 23-24
  3.3 Samples collection 25
  3.5 Samples preparation
    3.5.1 Preservation of samples 25
    3.5.2 Filteration of water sample 26
    3.5.3 Blank Solution preparation 26
  3.6 Samples analysis 26
  3.7 Statistical analysis 27

TABLE OF CONTENTS

Page

4 RESULTS
- 4.1 Introduction 28
- 4.2 Quality Control 28
  - 4.2.1 Blank solution 28-29
  - 4.2.2 Standard solution 29
- 4.3 Metal concentration
  - 4.3.1 Sodium 30
  - 4.3.2 Calcium 31
  - 4.3.3 Magnesium 32
  - 4.3.4 Manganese 33
  - 4.3.5 Iron 34
  - 4.3.6 Zinc 35
  - 4.3.7 Lead 36
  - 4.3.8 Copper 37
- 4.4 Comparison of metal concentration in water samples With the WHO and Malaysia Guidelines for Drinking Water Quality. 38

5 DISCUSSION
- 5.1 Quality Control
  - 5.1.2 Blank solution 39
  - 5.1.3 Standard solution 40
- 5.2 Metal 41
  - 5.2.1 Sodium 41-42
  - 5.2.2 Calcium 42-44
  - 5.2.3 Magnesium 44
  - 5.2.4 Manganese 45
  - 5.2.5 Iron 46
  - 5.2.6 Zinc 47-48
  - 5.2.7 Lead 48-50
  - 5.2.8 Copper 50

6 CONCLUSION 51

REFERENCES 52-56

APPENDICES
- A1 Mean metals concentration (Sodium, Calcium Magnesium) 57
- A2 Mean metals concentration (Manganese, Iron, Zinc) 58
- A3 Mean metals concentration (Lead and Copper) 59
- B1 Multiple comparison (Sodium) 60
- B2 Multiple comparison (Calcium) 61
- B3 Multiple comparison (Magnesium) 62
- B4 Multiple comparison (Manganese) 63
- B5 Multiple comparison (Iron) 64

TABLE OF CONTENTS

Page

APPENDICES (cont.)

B6 Multiple comparison (Zinc) 65
B7 Multiple comparison (Lead) 66
B8 Multiple comparison (Copper) 67
D1 Calibration Slope Value of Metal Analyzed (Sodium, Calcium) 68
D2 Calibration Slope Value of Metal Analyzed (Magnesium ,Manganese) 69
D3 Calibration Slope Value of Metal Analyzed (Iron, Zinc) 70
D4 Calibration Slope Value of Metal Analyzed (Lean, Copper) 71

PUBLICATION OF THE PROJECT UNDERTAKING 72

I dedicate this especially to my Lord, my Saviour, and my Redeemer, Jesus Christ.

Specially for my beloved parents and my one and only sister,

Mr. Ajis Sagam, Mdm. Jane Sipig and Ms. Ledionnie Ajis

For my beloved fiancé,

Mr. Kelvin Engkujoh Jawa.

For my future father, mother, brother and sister in-law,

Mr. Justin Jawa Angam, Mdm. Gupie Saban, Mr. Jason Rochon and Mrs. Jazmine Rochon

To my family and closest friends who supported me through the ups and downs of life.

Thank you all for your endless prayers.

May God Bless You All.

In loving memory of my departed grandfather,

Siping anak Barer
(1925-2000)

ABSTRACT

The study of metals concentration in drinking water in Universiti Putra Malaysia Bintulu Campus has been conducted from the 13th to 27th November 2006. A total of eight (8) metals such as sodium (Na), calcium (Ca) magnesium (Mg), manganese (Mn), iron (Fe), lead (Pb) and copper (Cu) was analyzed. The water samples were analyzed for these metals were from six (6) sampling stations. The results showed that most of the concentrations of metals in the water samples analyzed, were below the standard requirements approved on WHO and Malaysia Guidelines for Drinking Water Quality. However, there were three (3) metals that were analyzed were higher than the standards which were manganese, iron and lead. The contaminants of manganese, iron and lead might occur from sources such as plumbing fixtures and distribution pipelines. This may cause the water to have aesthetic problems such as undesirable taste and discolouration of water. Health wise threat could also occur especially for lead as it exceeds the standards in high amount. Therefore, this study suggest that the management of Universiti Putra Malaysia Bintulu Campus, should remove and replace the piping system with new ones especially the ones within the buildings.

ABSTRAK

Kajian tentang kepekatan logam di dalam air minuman di Universiti Putra Malaysia Kampus Bintulu telah dijalankan dari 13 sehingga 27 November 2006. Sebanyak lapan (8) jenis logam seperti natrium (Na), kalsium (Ca), magnesium (Mg), mangan (Mn), ferum (Fe), plumbum (Pb) and kuprum (Cu) telah dianilisis. Sampel air thelah dianalisis untuk kahadiran kelapan-lapan logam tersebut. Sampel air diambil dari enam (6) stesen pengambilan sampel. Keputusan mandapati bahawa kebanyakan logam yang dijumpai di dalam sampel air, tidak melibihi kepekatan piawai logam yang ditetapkan oleh *WHO Guidelines for Drinking Water Quality* dan *Malaysia Guidelines for Drinking Water Quality.* Walau bagaimanapun, terdapat tiga (3) logam yang dijumpai melebihi piawai yang ditetapkan. Logam tersebut adalah mangan, ferum dan plumbum. Kontaminasi ketiga-tiga logam ini mungkin berpunca daripada penyambungan paip dan juga paip yang menyalurkan air ke sekitar kawasan kampus. Kontaminasi logam ini dapat mengakibatkan air tidak enak untuk diminum dan warna air berubah. Bagi kontaminasi logam plumbum pula, ia mungkin akan mengakibatkan masalah kesihatan di kalangan warga kampus ini kerana ia melebihi piawai dengan jumlah kepekatan yang amat tinggi. Oleh itu, kajian mencadangkan pihak pengurusan Univeristi Putra Malaysia Kampus Bintulu, perlu membuang dan menukar paip-paip yang lama kepada yang baru, terutamanya paip didalam bangunan.

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I certify that this research project entitled "The Concentration of Metals In Drinking Water of University Putra Malaysia Bintulu Campus " has been examined and approved as a partial fulfillment of the requirement for the degree of Bachelor of Bioindustry Science in the Faculty of Agriculture and Food Sciences, Universiti Putra Malaysia Bintulu Campus.

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Date: 4th May 2007

LIST OF TABLES

Table number	Title	Page
2.1	Standard concentration of metals in drinking water.	19
3.1	List of materials used in this research	21
3.2	Sampling station	23
4.1	Blank solution concentration for each metal analyzed	28
4.2	Calibration slope value for each standard solution	29
4.3	Comparison of metal concentration in water samples with the WHO and Malaysia Guidelines For Drinking Water Quality	38

LIST OF FIGURES

Figure number	Title	Page
2.1	Pulsator clarifier treatment process diagram	6
2.2	Dissolve air flotation treatment plant diagram	8
3.1	The sampling area – Universiti Putra Malaysia Bintulu Campus	24
4.1	Mean sodium concentration in water samples, for three sampling dates (13/10/06, 20/10/06 and 27/10/06) from station 1 to 6	30
4.2	Mean calcium concentration in water samples, for three sampling dates (13/10/06, 20/10/06 and 27/10/06) from station 1 to 6	31
4.3	Mean magnesium concentration in water samples, for three sampling dates (13/10/06, 20/10/06 and 27/10/06) from station 1 to 6	32
4.4	Mean manganese concentration in water samples, for three sampling dates (13/10/06, 20/10/06 and 27/10/06) from station 1 to 6	33
4.5	Mean iron concentration in water samples, for three sampling dates (13/10/06, 20/10/06 and 27/10/06) from station 1 to 6	34
4.6	Mean zinc concentration in water samples, for three sampling dates (13/10/06, 20/10/06 and 27/10/06) from station 1 to 6	35
4.7	Mean lead concentration in water samples, for three sampling dates (13/10/06, 20/10/06 and 27/10/06) from station 1 to 6	36
4.8	Mean copper concentration in water samples, for three sampling dates (13/10/06, 20/10/06 and 27/10/06) from station 1 to 6	37

LIST OF ABREVIATIONS

AAS	Atomic Absorption Spectrophotometer
HNO_3	Nitric acid
mg/L	Milligram per litre
Na	Sodium (Natrium)
Ca	Calcium
Mg	Magnesium
Mn	Manganese
Fe	Iron
Zn	Zinc
Pb	Lead
Cu	Copper
WHO	World Health Organization
%	Percent

CHAPTER 1

INTRODUCTION

Water is a very essential element to all living being on earth. Human can live for a very long time without food but cannot live without water. Water is an important element used in everyday activities such as washing and cooking, and it also acts as a solvent and thermal transfer agent, which is part of the human metabolism. There are many types of water, which are the surface water, ground water and rainwater. Water, which is intended to be drunk by humans, is called drinking water. Drinking water sources are normally from the rivers, which are transported into a municipal water treatment plant. After treated, the water supplied should be safe from all undesirable substances that can harm our health.

In Malaysia, each state has their own water treatment plant which is run by either government or a privatized company. In Bintulu, the company that managed the water treatment processing is LAKU Management Sdn. Bhd. LAKU Management, manage the water treatment processing, from the cleansing of water (by treatments) till the distribution of water through out the whole Bintulu area. Distribution of water to Bintulu communities is reached out by water distribution pipelines.

However, after intense treatment to remove impurities in the water at the water treatment plant, the water that received by the community of Universiti Putra Malaysia Bintulu Campus, is not clean enough because the water is cloudy and seems to be unfit for drinking. The impurities in the water might contain metals, which are detrimental to health.

The water supply, which will be going to be analysed, is the main source of drinking water for the college community. The eight types of metals are; sodium, calcium, magnesium, manganese, iron, zinc, lead and copper.

There has been no study carried out in Universiti Putra Malaysia Bintulu Campus, on this water impurity issue. Therefore, this study has been carried out to analyze what are the metals which are available in the water and how this problem can be solve through suggestions of improvement.

The objectives of this study were :

a) To analyse sodium, calcium, magnesium, manganese, iron, lead and copper and compare the values with the WHO and Malaysia Guidelines for Drinking Water Quality.

b) To identify the cause of metal pollution in the water supply of Universiti Putra Malaysia Bintulu Campus.

CHAPTER 2

LITERATURE REVIEW

2.1 Drinking water

Water is a very valuable resource and it is essential in our everyday life, domestically and industrially. As such, it is now considered to be the blue gold of the 21st century. In today's world, the human population is increasing rapidly and so are the demands and usage of water. However, with this increase, they tend to degrade water quality, which would be devastating to the natural environment and consequently to human health (Pathak, 2002). People of the world today are very concerned about the safety and the cleanliness of the water that they are going to consume.

Water intended for human consumption should be not only "safe" but also "wholesome". Safe water is water that cannot harm the consumer, even when ingested over prolonged periods. Water may be safe, but if it has and unpleasant taste or appearances, it may drive the consumer to other less safe resources. Drinking water should therefore be not only completely safe, but also agreeable to use and wholesome. Such water may be termed "acceptable" or "potable". Hence safe and wholesome water is defined as water that is free from pathogenic disease, free from harmful chemical substances, with a pleasant taste and usable for domestic purposes. Water is said to be contaminated if it contains infective and parasitic agents, poisonous chemical substances, industrial or other wastes or sewage (Devasia, 2002). The term, polluted water is synonymous with contaminated water. Pollution and contamination are the result of human activity.

2.2 Water treatment process

The importance of good drinking water in maintaining human health was recognized early in history. However, it took centuries before people understood that their senses alone were not adequate judges of water quality. The earliest water treatments were based on filtering and driven by the desire to remove the taste and appearance of particles in water. Filtration was established as an effective means of removing particles from water and widely adopted in Europe during the eighteenth century. Exactly why a clean and reliable water supply was needed was not known until the second half of the nineteenth century, when the nature of infectious disease was first recognized and the ability of water supplies to transmit diseases such as cholera and typhoid was first demonstrated. After this, concerns about the quality of drinking water focused on disease-causing microorganisms (pathogens) in public water supplies. Scientists discovered that visible cloudiness, or turbidity, not only made the water look unappealing; it could also indicate a health risk. The turbidity was caused by particles in water that could harbour pathogens.

2.2.1 Bintulu water treatment process

In the area of Bintulu, the LAKU Management Sendirian Berhad does the water treatment processing and also the distribution of treated water. There are two methods of water treatments introduced by the LAKU Management, which are the Pulsator Clarifier Water Treatment Plant Water Treatment Process and the Dissolve air flotation Water Treatment Plant or DAF. However these two methods of water treatment are not used simultaneously at the same time. The LAKU management will only use one method at a time and the usage is based on rotation of the schedule. Each methods of these water processing are different from one another.

2.2.1.1 Pulsator Clarifier Water Treatment

The first water treatment method is the Pulsator Clarifier Water Treatment. In this method of water treatment processing, raw water is pumped from Sungai Sibiu and stored in the Sika raw water reservoir, which is formed by five earth dams. Raw water from Sika Reservoir is then pumped to the raw water tank. From the raw water tank, water is gravitated to the inlet works where the water treatment chemicals are added which are the Hydrated Lime and Aluminium Sulphate. The hydrated lime functions as the pH adjustor of the raw water. Aluminium sulphate functions as the coagulator of the coagulation process. Coagulation here means the small particles in the water are combined to form larger particles called flocs. At this coagulation stage, the metals, which are harmful, will be removed from the water. The metals will attach to form flocs along with other impurities. The water then flows into the vacuum chamber. When the water in the vacuum chamber reaches a preset level, the water is pushed through perforated pipes into the clarifiers. The flocs settle at the bottom of the clarifier and form a sludge blanket. The clarified water flows into the filters, which remove the suspended particles and the flocs that are not settled in the clarifiers, and lastly produce clean water. The filtered water is then added the following chemicals, which are liquid chlorine, hydrated lime and sodium silicofluoride. Liquid chlorine functions as a disinfectant. Hydrated lime is to adjust the water pH to approximately 7.0 to 7.5. Sodium silicofluoride is for the prevention of dental caries among children. The filtered water is then stored in the clear water well. This treated water will be pumped to the water tower and then distributed to the consumer.

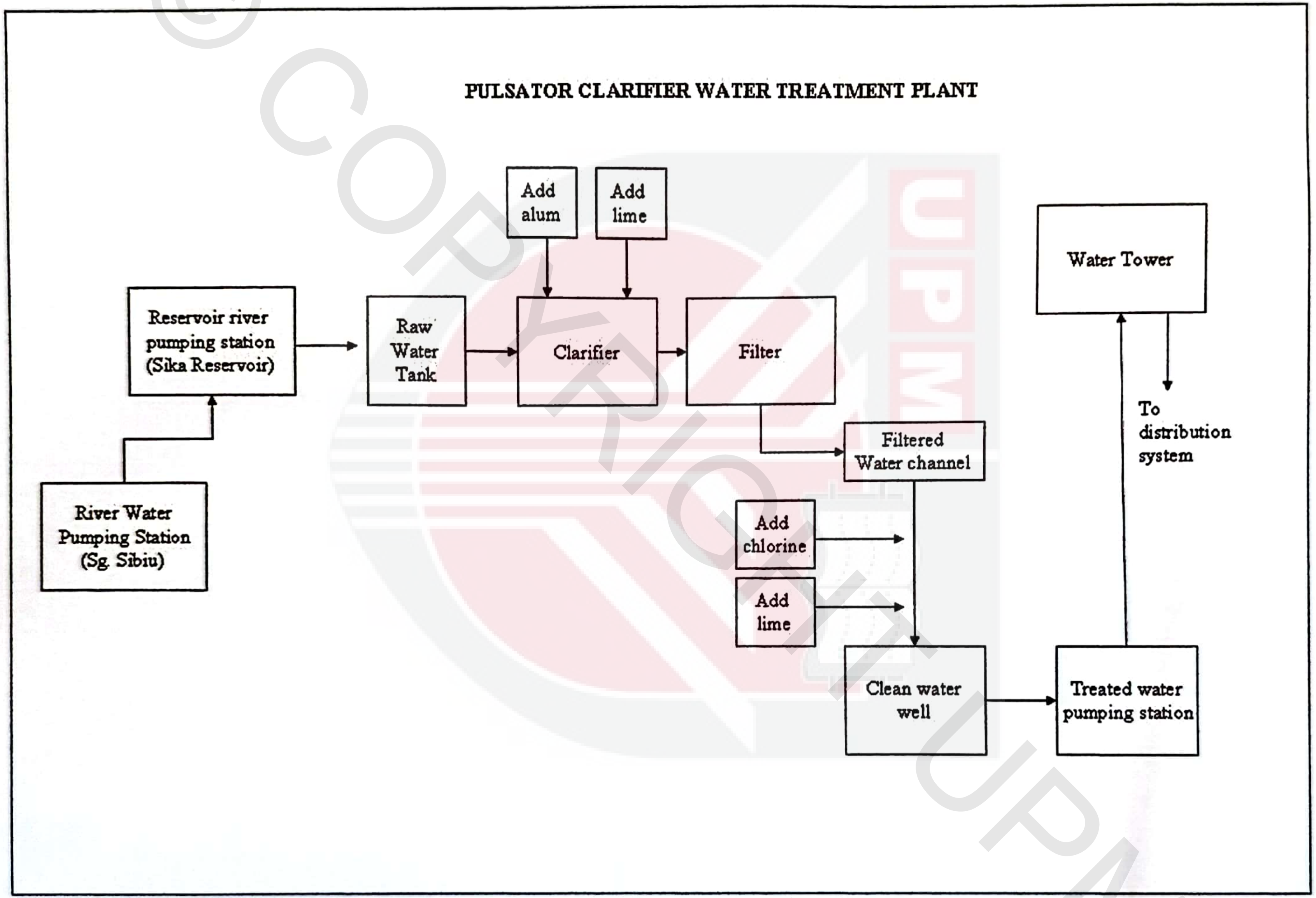


Figure 2.1: Pulsator clarifier treatment plant diagram.

2.2.1.2 Dissolve Air Flotation (DAF) Water Treatment

The second water treatment method is the Dissolve Air Flotation (DAF) Water Treatment Plant. The DAF water treatment plant draws water from the same source as the first method, which is from the Sika Reservoir. The water treatment chemicals, which are the hydrated lime and the aluminium sulphate, are added to the raw water in the flash mixing tank and the flocculation and coagulation process take place in the flocculator. Water saturated with dissolve air is injected into the water before the water enters the flotation or filtration tank. The millions of tiny air bubbles from the saturated water is released and attach to the particles or flocs in the water causing them to float to the surface for collection and removal, leaving the clarified water behind. The clarified water is then passed through the sand filters to filter off the remaining flocs and particles. This filtered water is then added chemicals such as mixed oxidant for disinfection, hydrated lime to adjust the pH to 7.0 to 7.5, and sodium silicofluoride for the prevention of dental caries among children. The treated water is stored in the clear water reservoir before it is pumped to the balancing reservoir. From the balancing reservoir the water is distributed to the consumers.

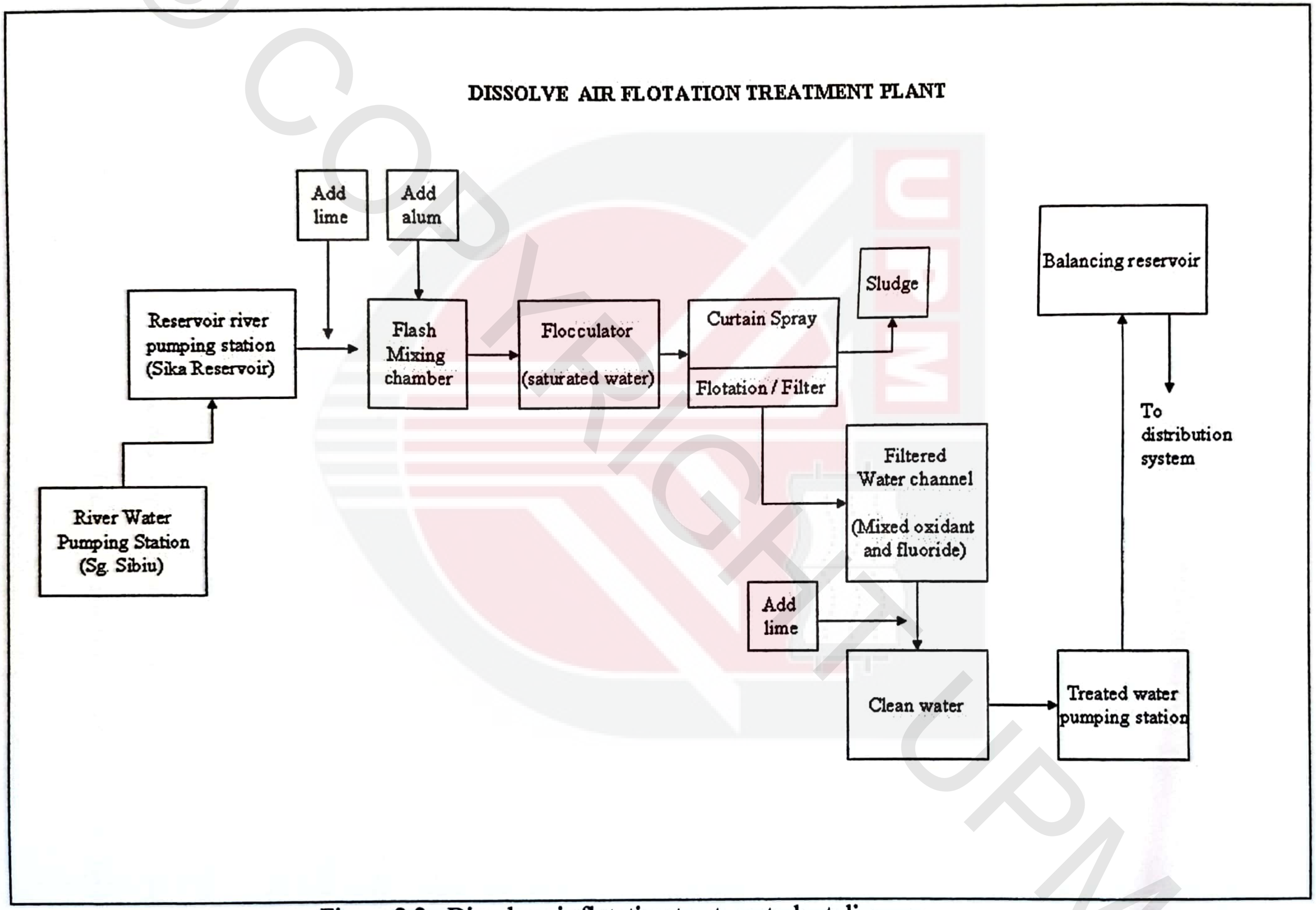


Figure 2.2: Dissolve air flotation treatment plant diagram.

2.3 Drinking water in Universiti Putra Malaysia Bintulu Campus

Universiti Putra Malaysia Bintulu Campus is a branch campus situated in Bintulu with an area width of 715.16 hectare. This campus has been operating in Bintulu in the year 1987, however closed down in the year 1992 for several national matters. This campus is reopen again on the 5th of November 2001.

Based on the date of the establishment of Universiti Putra Malaysia Bintulu Campus, which dated back in the 1987, the piping system of this university is approximately 20 years old. The old piping system causes problems whereby there are occurrences of metal constituents in the water. Water supply tends to undergo discolouration (in example, the colour of water is brownish due to high iron content), and undesirable taste of water occur when drinking the water. Besides the piping system, the storage tanks also might cause the water supply to undergo the problems stated above. This is because, during the first visit to the site, the tanks are not managed properly and it not clean at first sight.

The piping systems have been changed from galvanized iron piping to the high-density polyethylene piping system, in the year 2003. The main tank, which is LAKU Water Tank for Universiti Putra Malaysia, which is situated at the Borneo Best Project area, was last checked in the year 2005. After the last checked, there was no monitoring on the cleanliness of the tank. Without proper management of this tank, the water supply can be contaminated through many ways possible such as bird droppings or lizards' droppings and also the accumulation of metals in water from the piping and railings of the tanks. Therefore, this study will be carried out to determine whether there are occurances of metals in the water supply. Besides that, this study is also carry out to determine how safe the water is for consumption.

2.4 Metals

In this study, there were seven metals, which were analyzed, in which these metals are categorized into major metals and heavy metals. The seven metals are Sodium, Calcium, Magnesium, Manganese, Iron, Zinc, Lead and Copper. Sodium, magnesium and calcium are usually considered major metal ions in natural waters because their concentration are considerably higher than those of other cations (Hashemi, 2000). Manganese, iron, lead and copper are considered as heavy metals. Manganese, iron, and zinc are also abundant elements with relatively high concentrations in waters, compared to trace metals (Hashemi, 2000). Their concentration, however, might be quite low (at the µg/l level or even less) in certain unpolluted natural waters (Hashemi, 2000).

Heavy metals comprise of both the essential and non-essential trace metals that may be toxic to living beings. However the toxicity of these heavy metals to living beings depends on the properties of the heavy metals, the availability and also the concentration. The next explanations will be on the metal properties as well as their level of concentration in water and negative effects on human.

2.4.1 Sodium

Sodium is a soft, waxy, silvery reactive metal which belongs to the alkali metals that is abundant in natural compounds. Sodium salts are highly soluble in water and are leached from the terrestrial environment to groundwater and surface water. They are non-volatile and will thus be found in the atmosphere only in association with particulate matter (WHO, 2003). Sodium salts are used in water treatment, including softening, disinfection, corrosion control, pH adjustments and coagulation (NAS, 1977; WHO, 2003g). Sodium is a very important nutrient, which acts as a regulator to maintain the pH of the blood. Most water supplies contain less than 20mg of sodium per litre, but in some countries levels can exceed 250 mg/L. In general, sodium salts are not acutely toxic because of the efficiency with which mature kidneys excrete sodium. However, acute effects and death have been reported following accidental overdoses of sodium chloride (WHO, 2003g). Acute effects may include nausea, vomiting, convulsions, muscular twitching and rigidity, and cerebral and pulmonary oedema (Elton *et al.*, 1963; WHO, 2003g). Excessive salt intake seriously aggravates chronic congestive heart failure, and ill effects due to high levels of sodium in drinking water have been documented (WHO, 2003). The sodium standard concentration of WHO Guidelines for Drinking Water Quality 1993/1996 (which is currently in use by the Ministry of Health Sarawak and LAKU Management Sdn. Bhd.), is 200 mg/L.

2.4.2 Calcium

Calcium dissolve out of almost all rocks and is consequently detected in many waters (Bartram & Ballance, 1996). Calcium is an essential component of bones, teeth, shells, and plant structure. Calcium carbonate might be useful at low levels in water because it will produce a protective coating in pipes and distribution lines. At high concentrations however, it can clog pipes or produce harmful scales to boilers (Greenberg *et al.*, 1985; Hashemi, 2000). Concentrations of up to 100 mg of calcium per litre are fairly common in natural sources of water; sources containing over 200 mg of calcium per litre are rare (WHO, 2003). In drinking water, hardness is in the range 10–500 mg of calcium carbonate per litre (Marier *et al.*, 1979; WHO, 2003a). The calcium standard concentration of WHO Guidelines for Drinking Water Quality 1984 (which is currently in use by the Ministry of Health Sarawak and LAKU Management Sdn. Bhd.), is 500 mg/L.

2.4.3 Magnesium

Magnesium is a relatively abundant element in the earth's crust and hence a common constituent of natural water. Magnesium imparts hardness to water. Magnesium salts are soluble, natural water sources typically containing concentrations of up to 10 mg/litre. Such sources rarely contain more than 100 mg of magnesium per litre (WHO, 2003e). There are several known effects of excessive magnesium intake. In most large-scale studies, an inverse relationship between the hardness of drinking water and cardiovascular disease has been reported (Anderson *et al.*, 1975; WHO, 2003e). The results of several studies have suggested that a variety of other diseases are also inversely correlated with the hardness of water, including anencephaly (Crawford *et al.*, 1972; Bound *et al.*, 1981; WHO, 2003e) and various types of cancer

(Wigle *et al*., 1986; WHO, 2003e). The magnesium standard concentration of Malaysia Guidelines for Drinking Water Quality 1984 (which is currently in use by the Ministry of Health Sarawak and LAKU Management Sdn. Bhd.), is 150 mg/L.

2.4.4 Manganese

Manganese is one of the most abundant metals in the Earth's crust, usually occurring with iron. It is a component of over 100 minerals but is not found naturally in its pure (elemental) form (ATSDR, 2000; WHO, 2004f). Manganese occurs naturally in many surface water and groundwater sources and in soils that may erode into these waters. However, human activities are also responsible for much of the manganese contamination in water in some areas (WHO, 2004f). Levels in fresh water typically range from 1 to 200 μg/litre (Barceloux, 1999; WHO, 2004f). By the oral route, manganese is often regarded as one of the least toxic elements, although there is some controversy as to whether the neurological effects observed with inhalation exposure also occur with oral exposure. Several case reports of oral exposure to high doses of manganese have described neurological impairment as an effect, but the quantitative and qualitative details of exposure necessary to establish direct causation are lacking. Another individual who ingested 1.8 mg of potassium permanganate per kg of body weight per day for 4 weeks developed symptoms similar to Parkinson disease 9 months later (Holzgraefe *et al*., 1986; Bleich *et al*., 1999; WHO, 2004f). An epidemiological study in Japan described adverse effects in humans consuming manganese dissolved in drinking water, probably at a concentration close to 28 mg/litre (Kawamura *et al*., 1941; WHO, 2004f). The manganese was derived from 400 dry-cell batteries buried near a drinking water well. Fifteen cases of poisoning were reported among 25 persons examined, with symptoms including lethargy, increased muscle tone, tremor and mental disturbances. The manganese standard concentration of WHO Guidelines for Drinking Water Quality 1993/1996 (which is currently in use by the Ministry of Health Sarawak and LAKU Management Sdn. Bhd.), is 0.1 mg/L.

2.4.5 Iron

Iron is the second most abundant metal in the earth's crust, of which it accounts for about 5%. Elemental iron is rarely found in nature, as the iron ions Fe^{2+} and Fe^{3+} readily combine with oxygen- and sulfur-containing compounds to form oxides, hydroxides, carbonates, and sulfides. Iron is most commonly found in nature in the form of its oxides (WHO, 2003c). In drinking-water supplies, iron (II) salts are unstable and are precipitated as insoluble iron (III) hydroxide, which settles out as a rust-coloured silt. Iron also promotes undesirable bacterial growth ("iron bacteria") within a waterworks and distribution system, resulting in the deposition of a slimy coating on the piping (DNHWC, 1990; WHO, 2003). A higher level of iron gives a bittersweet, astringent taste to water (Hashemi, 2000; WHO, 2003c). Concentrations of iron in drinking water are normally less than 0.3 mg/litre but may be higher in countries where various iron salts are used as coagulating agents in water-treatment plants and where cast iron, steel, and galvanized iron pipes are used for water distribution. The average lethal dose of iron is 200–250 mg/kg of body weight, but death has occurred following the ingestion of doses as low as 40 mg/kg of body weight (N.R.C., 1979; WHO, 2003c). Autopsies have shown haemorrhagic necrosis and sloughing of areas of mucosa in the stomach with extension into the submucosa. Chronic iron overload results primarily from a genetic disorder (haemochromatosis) characterized by increased iron absorption and from diseases that require frequent transfusions (Bothwell *et al.*, 1979; WHO, 2003c). The iron standard concentration of WHO Guidelines for Drinking Water Quality 1993/1996 (which is currently in use by the Ministry of Health Sarawak and LAKU Management Sdn. Bhd.), is 0.3 mg/L.

2.4.6 Zinc

Zinc is an important essential element in both human and animal growth (Hashemi, 2000). Zinc occurs in small amounts in almost all igneous rocks. The principal zinc ores are sulfides, such as sphalerite and wurzite (Elinder, 1986; WHO, 2003h). The natural zinc content of soils is estimated to be 1 to 300 mg/kg (Nriagu, 1980; WHO, 2003h). It exists with only the valence of 2+ in natural waters (Hashemi, 2000). Zinc imparts an undesirable astringent taste to water. Tests indicate that 5% of a population could distinguish between zinc-free water and water containing zinc at a level of 4 mg/litre (as zinc sulfate). The detection levels for other zinc salts were somewhat higher. Water containing zinc at concentrations in the range 3–5 mg/litre also tends to appear opalescent and develops a greasy film when boiled (Cohen *et al.*, 1960; WHO, 2003h). Zinc is used in the production of corrosion-resistant alloys and brass, and for galvanizing steel and iron products.

In tap water, the zinc concentration can be much higher as a result of the leaching of zinc from piping and fittings (Nriagu, 1980; WHO, 2003h). There is no known disease associated with the excessive of zinc intake through consumption of drinking water. The zinc standard concentration of WHO Guidelines for Drinking Water Quality 1993/1996 (which is currently in use by the Ministry of Health Sarawak and LAKU Management Sdn. Bhd.), is 3 mg/L.

2.4.7 Lead

Lead is the commonest of the heavy elements, accounting for 13 mg/kg of the earth's crust. Several stable isotopes of lead exist in nature, including, in order of abundance, ^{208}Pb, ^{206}Pb, ^{207}Pb, and ^{204}Pb. Lead is a soft metal. Lead is used in the production of lead acid batteries, solder, alloys, cable sheathing, pigments, rust inhibitors, ammunition, glazes, and plastic stabilizers (WHO, 2003d). From a drinking-water perspective, the almost universal use of lead compounds in plumbing fittings and as solder in water-distribution systems is important. Lead pipes may be used in older distribution systems and plumbing (Quinn *et al.*, 1990; WHO, 2003d). Lead is present in tap water to some extent as a result of its dissolution from natural sources but primarily from household plumbing systems in which the pipes solder, fittings, or service connections to homes contain lead. PVC pipes also contain lead compounds that can be leached from them and result in high lead concentrations in drinking water. The amount of lead dissolved from the plumbing system depends on several factors, including the presence of chloride and dissolved oxygen, pH, temperature, water softness, and standing time of the water, soft, acidic water being the most plumbosolvent (Schock, 1989, 1990; WHO, 2003d). Although lead can be leached from lead piping indefinitely, it appears that the leaching of lead from soldered joints and brass taps decreases with time (Levin *et al.*, 1989; WHO, 2003d). The level of lead in drinking water may be reduced by corrosion-control measures such as the addition of lime and the adjustment of the pH in the distribution system from less than 7 to 8–9 (Moore *et al.*, 1981; Sherlock *et al.*, 1984; WHO, 2003d). Lead is a cumulative general poison, infants, children up to 6 years of age, the fetus, and pregnant women being the most susceptible to adverse health effects. Its effects on the central nervous system can be particularly serious. Soldered connections in recently built homes fitted with copper piping can release enough lead (210 to390 µg/litre) to cause intoxication in children (Cosgrove *et al.*, 1989; WHO, 2003d). Overt signs of acute intoxication include dullness, restlessness, irritability, poor attention span, headaches, muscle tremor, abdominal cramps, kidney damage, hallucinations, and loss of memory, encephalopathy occurring at blood lead levels of 100–120 µg/dl in adults and 80 to 100 µg/dl in children. Signs of chronic lead toxicity, including tiredness, sleeplessness, irritability, headaches, joint pain, and gastrointestinal symptoms, may appear in adults at blood lead levels of 50–80 µg/dl. The lead standard concentration of WHO Guidelines for Drinking Water Quality 1993/1996 (which is currently in use by the Ministry of Health Sarawak and LAKU Management Sdn. Bhd.), is 0.01 mg/L.

2.4.8 Copper

Copper is a transition metal that is stable in its metallic state and forms monovalent (cuprous) and divalent (cupric) cations (WHO, 2004b). Dissolved copper can sometimes impart a light blue or blue-green colour and an unpleasant metallic, bitter taste to drinking water. The concentration at which 50% of 61 volunteers could detect the taste of copper (in example; taste threshold) as the sulfate or chloride salt in tap or demineralized water ranged from 2.4 to 2.6 mg/litre (Zacarias *et al.*, 2001). The taste threshold increased in the presence of other solutes (Olivares *et al.*, 1996a; Zacarias *et al.*, 2001). Blue to green staining of porcelain sinks and plumbing fixtures occurs from copper dissolved in tap water. Copper is found in surface water, groundwater, seawater and drinking water, but it is primarily present in complexes or as particulate matter (ATSDR, 2002). Copper concentrations in surface waters ranged from 0.0005 to 1 mg/litre in several studies in the USA; the median value was

0.01 mg/litre (ATSDR, 2002). The acute lethal dose for adults lies between 4 and 400 mg of copper (II) ion per kg of body weight, based on data from accidental ingestion and suicide cases (Chuttani *et al*., 1965; Jantsch *et al*., 1984–1985; Agarwal *et al*., 1993).

Individuals ingesting large copper in drinking water suffer with gastrointestinal bleeding, haematuria, intravascular hamolysis, mathaemoglobinaemia, hepatocellular toxicity, acute renal failure and oliguria (Agarwal *et al*., 1993). At lower doses, copper ions can cause symptoms typical of food poisoning (headache, nausea, vomiting, diarrhoea). Records from case-study reports of gastrointestinal illness induced by copper from contaminated water or beverages plus public health department reports for 68 incidents indicate an acute onset of symptoms. Symptoms generally appear after 15–60 min of exposure; nausea and vomiting are more common than diarrhoea (Wyllie, 1957; Spitalny *et al*., 1984; Knobeloch *et al*., 1994; Low *et al*., 1996; Stenhammar, 1999). The copper standard concentration of WHO Guidelines for Drinking Water Quality 1984 (which is currently in use by the Ministry of Health Sarawak and LAKU Management Sdn. Bhd.), is 1 mg/L.

2.4.9 Metal concentration standards for drinking water

The table below shows the standard concentration of the metals in drinking water. The standard in use are based on the standards of the World Health Organization and also Malaysia. These standards are currently in use by the Ministry of Health Sarawak and LAKU Management Sdn. Bhd..

Table 2.1: Standard concentration of the metals in drinking water

Element	Standard concentration (mg/L)	Source of reference
Sodium	200	WHO2
Calcium	500	WHO1
Magnesium	150	MAL 1990
Manganese	0.1	WHO2
Iron	0.3	WHO2
Zinc	3	WHO2
Lead	0.01	WHO2
Copper	1	WHO1

Keywords :

1) WHO 1 : Indicates WHO Guidelines for Drinking Water Quality 1984
2) WHO 2 : Indicates WHO Guidelines for Drinking Water Quality 1993/1996
3) MAL1990 : Indicates values adapted for Malaysian conditions (1990)

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this topic, the materials and methods, which will be use in this research, will be explained completely and precisely. This research requires fieldwork and also laboratory analysis. The fieldwork is where raw water samples are collected from different water tanks, and the laboratory analysis involves with the analysis of heavy metal contents in the raw water samples taken. The fieldwork and laboratory analysis is done according to the method prescribed by Bartram and Balance (1996) and previous research, which have been done by Tamasi and Cini (2003).

3.2 Materials and equipments

Materials used for this research were prepared before undergoing sample collection and laboratory analysis. The table below shows the list of materials, which include chemicals and laboratory equipments.

Table 3.1: List of materials used in this research.

Materials (chemicals, laboratory equipments)	Distributor
1. Asid Nitric, HNO_3 70% conc.	J.T Baker
2. Standard solution Na, Ca, Mg, Mn, Fe, Zn and Pb	Perkin-Elmer
3. Polyethylene bottles 500mL	-
4. Cellulose Nitrate Membrane Filter 0.45μm	Whatman
5. Glass beaker 250mL and 50mL	Pyrex
6. Volumetric flask 1000mL	Pyrex
7. Measuring cylinder 10mL	Pyrex
8. Vaccum filter	-
9. Plastic vials (Pill Box)	-
10. Latex gloves	-
11. Ice chest	Coleman
12. Ice	-
13. Celotape	-
14. Atomic Asorption Spectophotometer (AAS) -AAnalyst^{TM} 800	Perkin-Elmer
15. Drinking water samples	-

3.2.1 Sterilization of equipments

The field and laboratory equipments must be sterilized first before usage in order to avoid any bacterial contamination that could deteriorate the results. All equipments were washed using the acid wash method. Nitric acid of 70% concentration was used in this method. Before washing the equipments, firstly the acid nitric was diluted with the distilled water. The equation M1V1 = M2V2 was used, in order to determine the amount of nitric acid needed to wash all the equipments.

The equation, M1V1 = M2V2 is whereby: -

M_1 = The concentration of nitric acid to be used for dilution.
V_1 = The volume of HNO_3 needed.
M_2 = The concentration of nitric acid which is needed.
V_2 = HNO_3 volume needed for dilution.

After the acid nitric was diluted, then the equipments were placed in an enclosed container (which in this research case, the coleman ice chest was being used). The diluted acid nitric was then poured onto the equipments. The equipments later on was left for 24 hours in the enclose container. After 24 hours, the equipments were taken out and washed using only distilled water and left to air dry on clean trays.

3.3 Study area

The areas of sampling were done within the area of Universiti Putra Malaysia Bintulu campus. There were 3 areas of sampling location, which were the Universiti Putra Malaysia Water Reservoir Tank, KK1 and lastly KK2. There was a total of six sampling stations whereby each of the three (3) sampling areas; there was two (2) stations for sample collection. At the Universiti Putra Malaysia Water Reservoir Tank, the drinking water samples was taken from the piping where the water flows into the tank from the LAKU Water Treatment Plant; and also water which is already available in the tank. At KK1 and KK2, water samples were collected from the pipe attached to the main tanks and also from the pipe available in the cooking area. Each sampling points was assigned as Station 1 till Station 6. Below is the table of sampling station: -

Table 3.2: Sampling station

Sampling station	Area
Station 1	Universiti Putra Malaysia Bintulu Campus Water Reservoir (Water Inlet)
Station 2	Universiti Putra Malaysia Bintulu Campus Water Reservoir (Tank)
Station 3	KK1 Water Tank
Station 4	KK1 Pipe
Station 5	KK2 Water Tank
Station 6	KK2 Pipe

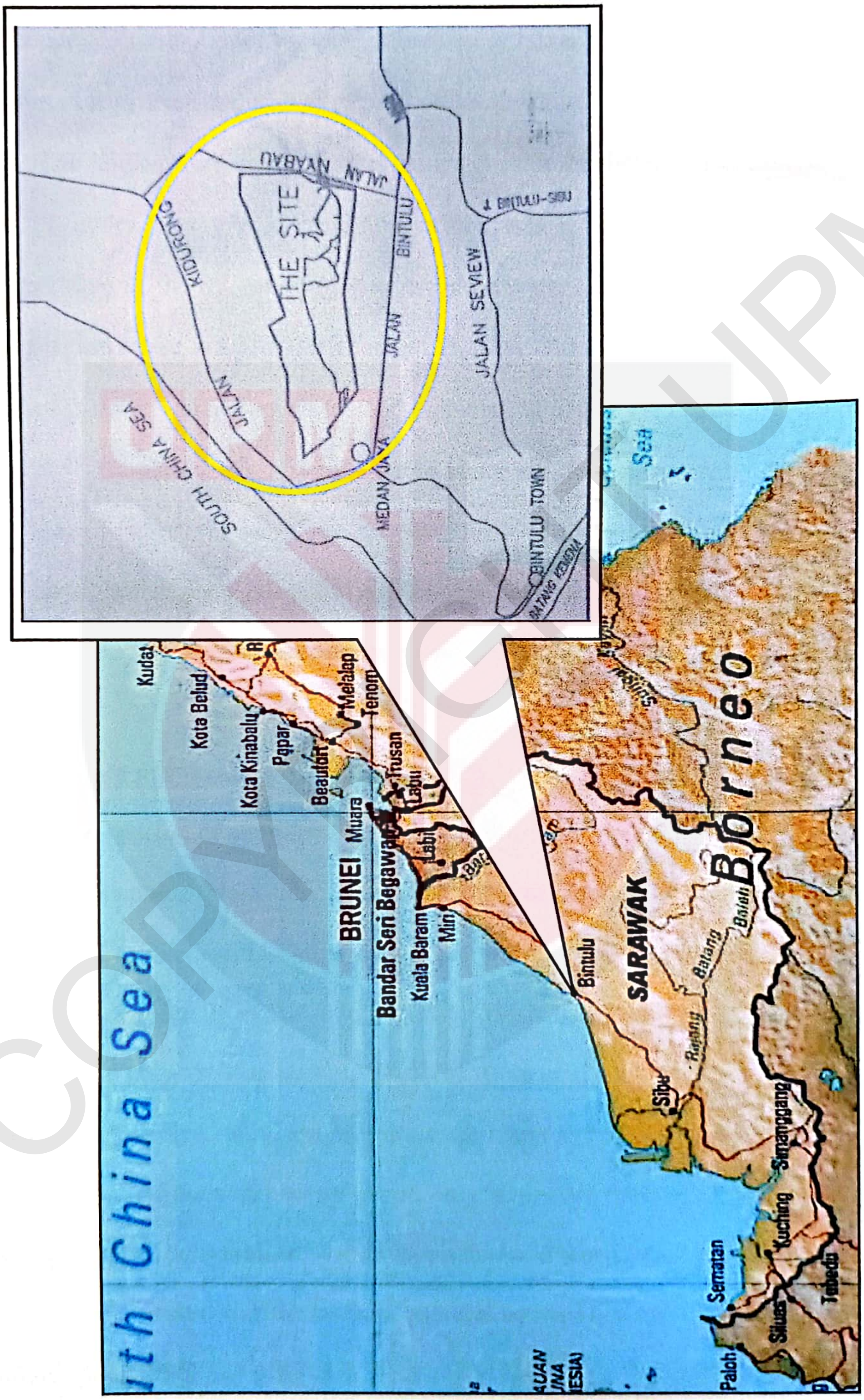


Figure 3.1: The sampling area - Universiti Putra Malaysia Bintulu Campus

3.4 Samples collection

In this study, the samples will be the water taken from each sampling station. During the sampling activity, water samples, which were taken from each sampling station, were stored into sterilized polyethylene bottles (Bartram *et al.*, 1996; Tamasi *et al.*, 2003). The bottles were then stored in the ice chest immediately. The samples must be stored under a very cold condition, which was a -4 degree Celsius to avoid deteriorization of the important properties in the water and also to avoid immediate contamination while on field (Bartram *et al.*, 1996; Tamasi *et al.*, 2003). Sampling was done 3 times which was on the 13th October 2006, 20th October 2006 and lastly on the 22nd October 2006. Every sample taken was labeled properly and clearly. There are a total of six sampling stations. Each of these sampling stations, three replicates of water were taken for analysis for each date which means N=9. The overall total for the water samples were 54 samples.

3.5 Sample preparation

3.5.1 Preservation of samples

The water samples were then taken to the laboratory for preservation. The preservation of water samples requires nitric acid of 70% concentration. The amount of acid nitric needed is in the ratio of 1:10. Which means for every liter of water sample (in the polyethylene bottle), 10 mL of nitric acid was needed to preserve the water samples. In this study, the samples were taken and stored into 500mL bottles. Therefore, each of the water samples will only be needed 5mL of nitric acid of 70% concentration for preservation. After applying acid nitric, the samples were then stored into the chiller and let to chill under a temperature of - 4 degrees Celsius (Bartram *et al.*, 1996)

3.5.2 Filteration of water samples

The water samples were filtered first before running test through the Atomic Absorption Flame Spectrophotometer (AAS). Then the water samples were filtered using the Vacuum Filter. A 0.45 µm cellulose nitrate membrane filter was placed into the vacuum filter, which filters the dirt, or debris, which cannot be seen through the naked eye (Tamasi *et al.*, 2003). The water sample, which has been filtered, was stored into sterilized pillboxes or clear plastic vials before sending for analysis using the AAS. The samples were labeled clearly on the plastic vials to avoid experimental error.

3.5.3 Blank solution preparation

Blank solution must be prepared before sample analyses are done. The main objective of preparing a blank sample is to detect any heavy metal contamination on the sample, which is going to be analyzed. The heavy metal contamination might come from, laboratory apparatus which have not been cleaned properly or the chemical which have been used to clean the laboratory apparatus. The blank solution for this study was distilled water added with 70% concentration of Nitric acid. This blank solution was done this way because the water samples have been added 70% concentration of Nitric acid, as a preservative to avoid contamination.

3.6 Sample analysis

The samples were analyzed for metals concentration using the Atomic Absorption Flame Spectrophotometer (AAS) (Bartram *et al.*, 1996). Analyses of samples were done in the month of November.

3.7 Statistical analysis

Results for all samples from each station were tested using completely randomized design (CRD) test or one way ANOVA using Statistical Package for Social Science (SPSS) Version 13.0, to determine whether there was significance or no significance between all results obtained for each station. The completely randomized design was done at a 95 % confidence level with $p \geq 0.05$.

CHAPTER 4

RESULTS

4.1 Introduction

In this chapter the results from all laboratory analysis was presented. There were two results, which are the quality control results and also the metal concentration results.

4.2 Quality Control

Quality control is a procedure that has to be done in any research activity to ensure there is no contamination from any source of anywhere possible. In this study, the quality control that has been done was the preparation of blank solution and also the analyzing of the standard solution.

4.2.1 Blank Solution

Blank solution is a solution, which have been prepared, without adding in any of the samples, which are going to be analyzed. The blank solution was analyzed through the AAS first before analyzing the water samples.

Table 4.1: Blank solution concentration for each metal analyzed.

	Blank solution concentration (mg/L)							
Month	Na	Ca	Mg	Mn	Fe	Zn	Pb	Cu
November	-	-	-	-	-	-	-	-

- : No concentration value

Table 4.1 shows the concentration for each of the major and heavy metals concentration in the blank solution. However, there were no values presented, as there was no elements found in the blank solution.

4.2.2 Standard solution

The next procedure in quality control is the standard solution testing. Below is the calibration slope table.

Table 4.2: Calibration slope value for each standard solution

	Calibration slope value							
Month	Na	Ca	Mg	Mn	Fe	Zn	Pb	Cu
Nov	0.9576	0.9824	0.9961	0.9990	0.9979	0.9976	0.9751	0.9948

Table 4.2 shows the calibration slope value for each standard solution test, which has been run using the AAS machine.

4.3 Metal concentration

4.3.1 Sodium

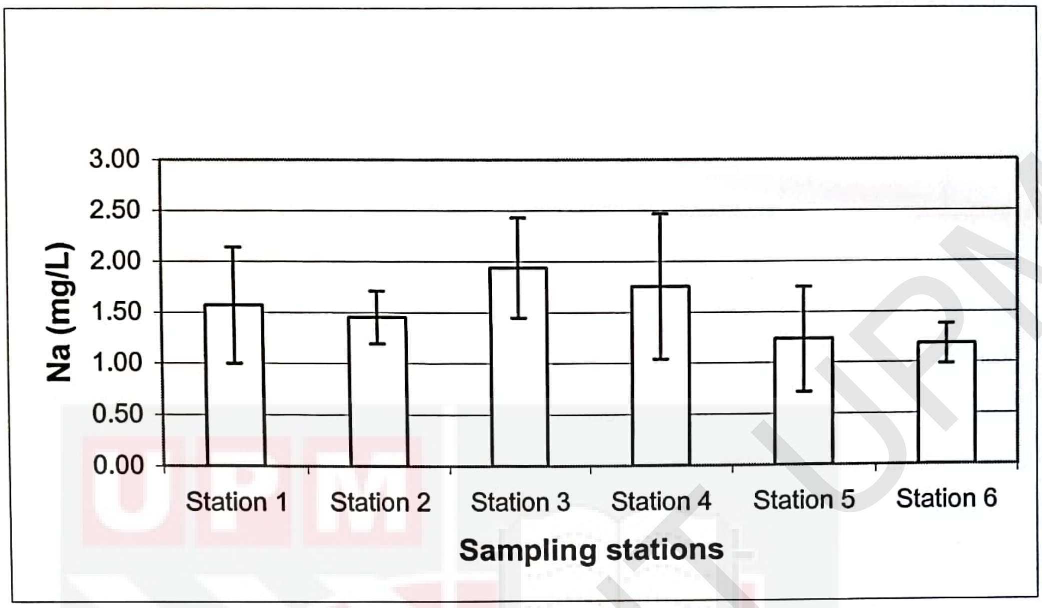


Figure 4.1: Mean sodium concentration in water samples, for three sampling dates (13/10/06, 20/10/27 and 27/10/06) from station 1 to 6.

Table 4.1 shows the mean sodium concentration in water samples for the three sampling dates stated above. The values from station 1 to station 6 were ranging from 1.182±0.197 mg/L to 1.937±0.493 mg/L.

Keyword :
1) Station 1 : Universiti Putra Malaysia Bintulu Campus Water Reservoir (Water Inlet)
2) Station 2 : Universiti Putra Malaysia Bintulu Campus Water Reservoir (Tank)
3) Station 3 : KK1 Water Tank
4) Station 4 : KK1 Pipe
5) Station 5 : KK2 Water Tank
6) Station 6 : KK2 Pipe

4.3.2 Calcium

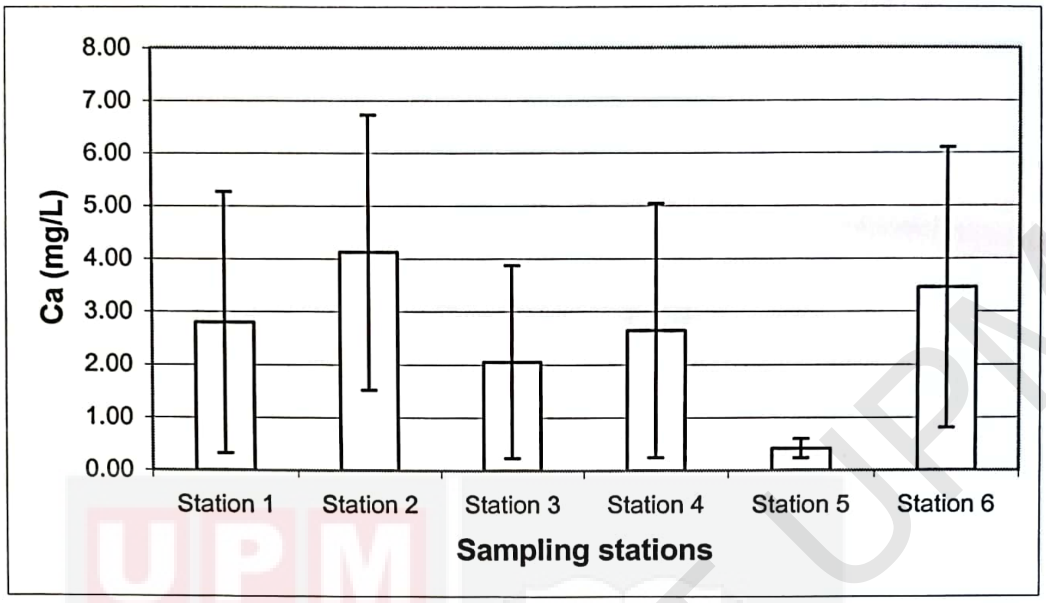


Figure 4.2: Mean calcium concentration in water samples, for three sampling dates (13/10/06, 20/10/27 and 27/10/06) from station 1 to 6.

Table 4.2 shows the mean calcium concentration in water samples for the three sampling dates stated above. The values from station 1 to station 6 were ranging from 0.417±0.182 mg/L to 4.124±2.603 mg/L.

Keyword :
1) Station 1 : Universiti Putra Malaysia Bintulu Campus Water Reservoir (Water Inlet)
2) Station 2 : Universiti Putra Malaysia Bintulu Campus Water Reservoir (Tank)
3) Station 3 : KK1 Water Tank
4) Station 4 : KK1 Pipe
5) Station 5 : KK2 Water Tank
6) Station 6 : KK2 Pipe

4.3.3 Magnesium

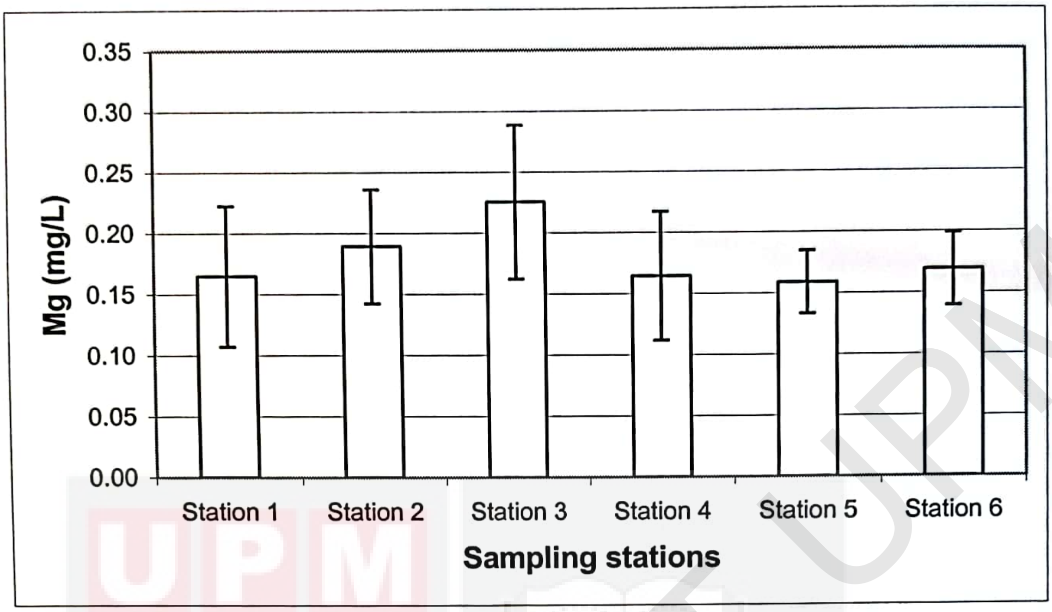


Figure 4.3: Mean magnesium concentration in water samples, for three sampling dates (13/10/06, 20/10/27 and 27/10/06) from station 1 to 6.

Table 4.3 shows the mean magnesium concentration in water samples for the three sampling dates stated above. The values from station 1 to station 6 were ranging from 0.159±0.026 mg/L to 0.225±0.063 mg/L.

Keyword :
1) Station 1 : Universiti Putra Malaysia Bintulu Campus Water Reservoir (Water Inlet)
2) Station 2 : Universiti Putra Malaysia Bintulu Campus Water Reservoir (Tank)
3) Station 3 : KK1 Water Tank
4) Station 4 : KK1 Pipe
5) Station 5 : KK2 Water Tank
6) Station 6 : KK2 Pipe

4.3.4 Manganese

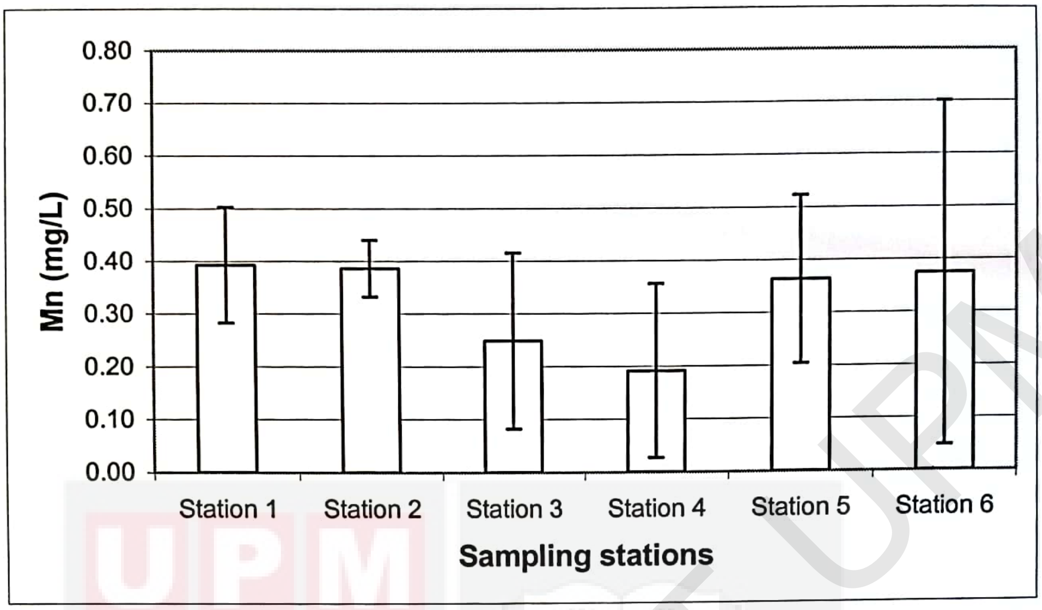


Figure 4.4: Mean manganese concentration in water samples, for three sampling dates (13/10/06, 20/10/27 and 27/10/06) from station 1 to 6.

Table 4.4 shows the mean manganese concentration in water samples for the three sampling dates stated above. The values from station 1 to station 6 were ranging from 0.192±0.164 mg/L to 0.392±0.110 mg/L.

Keyword :
1) Station 1 : Universiti Putra Malaysia Bintulu Campus Water Reservoir (Water Inlet)
2) Station 2 : Universiti Putra Malaysia Bintulu Campus Water Reservoir (Tank)
3) Station 3 : KK1 Water Tank
4) Station 4 : KK1 Pipe
5) Station 5 : KK2 Water Tank
6) Station 6 : KK2 Pipe

4.3.5 Iron

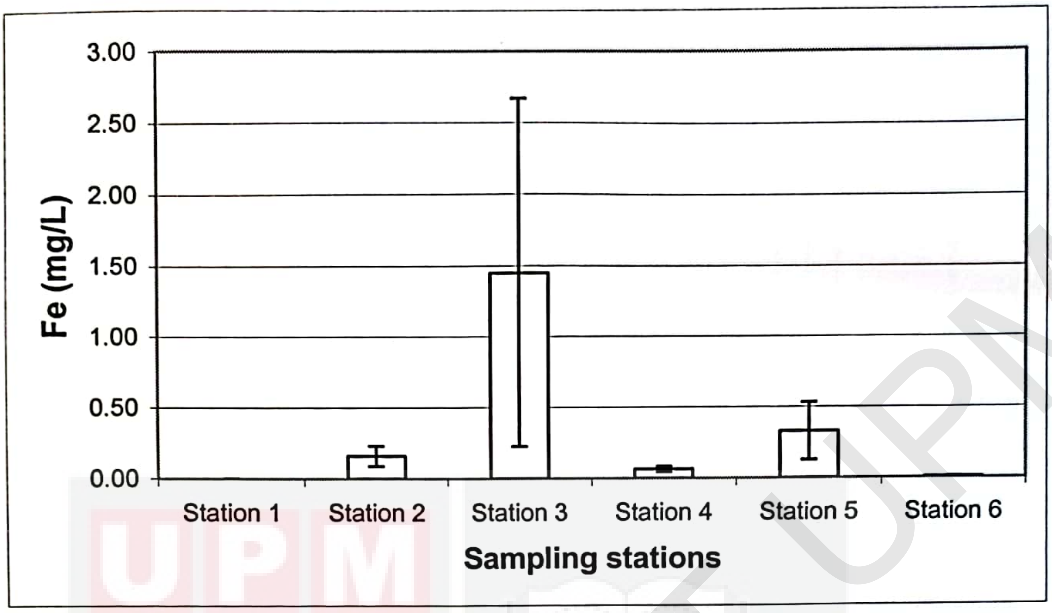


Figure 4.5: Mean iron concentration in water samples, for three sampling dates (13/10/06, 20/10/27 and 27/10/06) from station 1 to 6.

Table 4.5 shows the mean iron concentration in water samples for the three sampling dates stated above. The values from station 1 to station 6 were ranging from 0.000±0.000 mg/L to 1.447±1.220 mg/L.

Keyword :
1) Station 1 : Universiti Putra Malaysia Bintulu Campus Water Reservoir (Water Inlet)
2) Station 2 : Universiti Putra Malaysia Bintulu Campus Water Reservoir (Tank)
3) Station 3 : KK1 Water Tank
4) Station 4 : KK1 Pipe
5) Station 5 : KK2 Water Tank
6) Station 6 : KK2 Pipe

4.3.6 Zinc

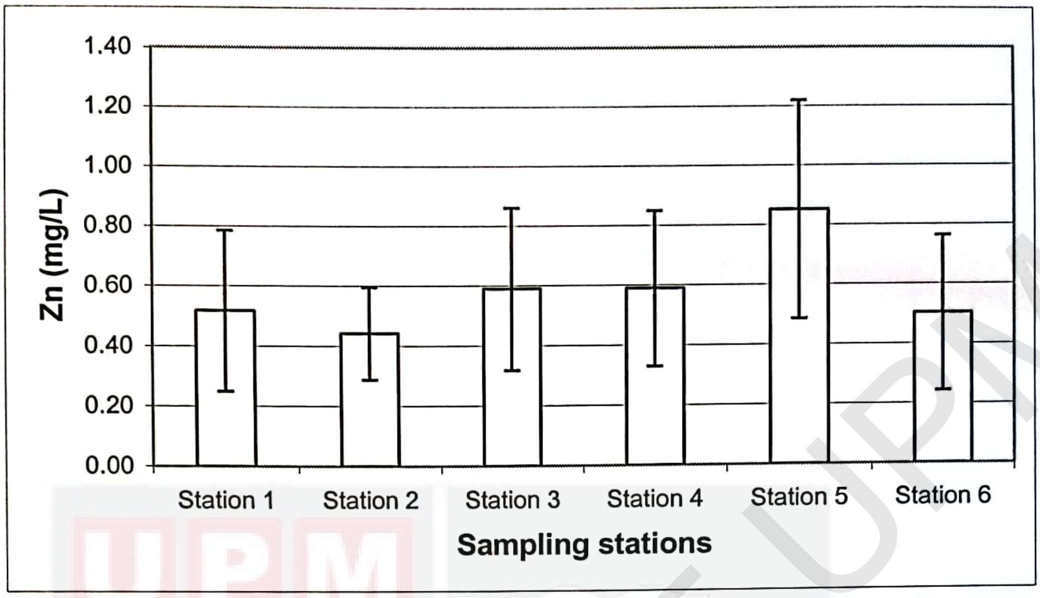


Figure 4.6: Mean zinc concentration in water samples, for three sampling dates (13/10/06, 20/10/27 and 27/10/06) from station 1 to 6.

Table 4.6 shows the mean zinc concentration in water samples for the three sampling dates stated above. The values from station 1 to station 6 were ranging from 0.442±0.152 mg/L to 0.852±0.367 mg/L.

Keyword :
1) Station 1 : Universiti Putra Malaysia Bintulu Campus Water Reservoir (Water Inlet)
2) Station 2 : Universiti Putra Malaysia Bintulu Campus Water Reservoir (Tank)
3) Station 3 : KK1 Water Tank
4) Station 4 : KK1 Pipe
5) Station 5 : KK2 Water Tank
6) Station 6 : KK2 Pipe

4.3.7 Lead

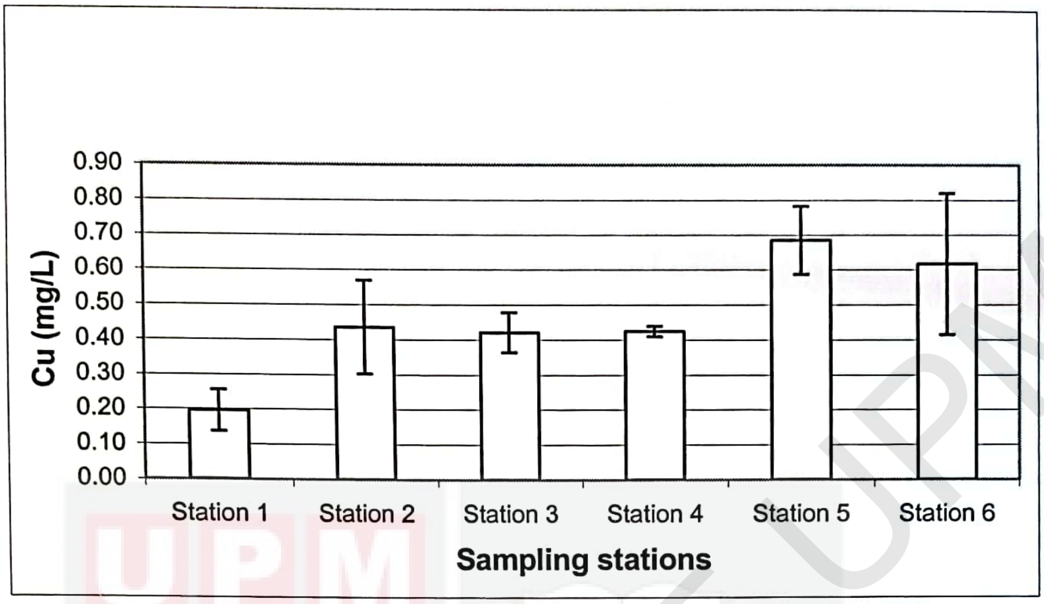


Figure 4.7: Mean lead concentration in water samples, for three sampling dates (13/10/06, 20/10/27 and 27/10/06) from station 1 to 6.

Table 4.7 shows the mean lead concentration in water samples for the three sampling dates stated above. The values from station 1 to station 6 were ranging from 0.196±0.059 mg/L to 0.685±0.098 mg/L.

Keyword :
1) Station 1 : Universiti Putra Malaysia Bintulu Campus Water Reservoir (Water Inlet)
2) Station 2 : Universiti Putra Malaysia Bintulu Campus Water Reservoir (Tank)
3) Station 3 : KK1 Water Tank
4) Station 4 : KK1 Pipe
5) Station 5 : KK2 Water Tank
6) Station 6 : KK2 Pipe

4.3.8 Copper

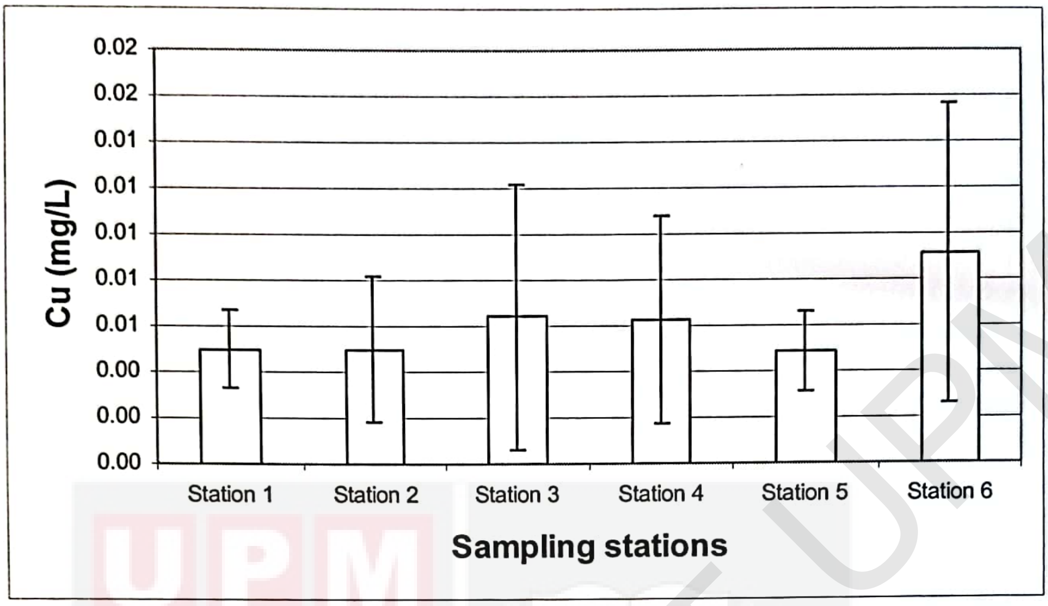


Figure 4.8: Mean copper concentration in water samples, for three sampling dates (13/10/06, 20/10/27 and 27/10/06) from station 1 to 6.

Table 4.8 shows the mean copper concentration in water samples for the three sampling dates stated above. The values from station 1 to station 6 were ranging from 0.005±0.002 mg/L to 0.009±0.007 mg/L.

Keyword :
1) Station 1 : Universiti Putra Malaysia Bintulu Campus Water Reservoir (Water Inlet)
2) Station 2 : Universiti Putra Malaysia Bintulu Campus Water Reservoir (Tank)
3) Station 3 : KK1 Water Tank
4) Station 4 : KK1 Pipe
5) Station 5 : KK2 Water Tank
6) Station 6 : KK2 Pipe

4.4 Comparison of metal concentration in water samples with the WHO and Malaysia Guidelines For Drinking Water Quality

Table 4.3 : Comparison of metal concentration with WHO and Malaysia Guidelines for Drinking Water Quality

Element	Guidelines for Drinking Water Quality (Standard concentration mg/L)	Results obtained after analysis of water samples
Sodium	200	1.182 - 1.937 mg/L
Calcium	500	0.417 - 4.124 mg/L
Magnesium	150	0.159 - 0.225 mg/L
Manganese	0.1	0.192 - 0.392 mg/L
Iron	0.3	0.006 - 1.447 mg/L
Zinc	3	0.442 - 0.852 mg/L
Lead	0.01	0.196 - 0.685 mg/L
Copper	1	0.005 - 0.009 mg/L

CHAPTER 5

DISCUSSION

In this section, the results of the quality control, and the metals concentration results were further discussed.

5.1 Quality control

5.1.1 Blank solution

The main objective of preparing a blank sample is to detect any heavy metal contamination on the sample, which is going to be analyzed. The heavy metal contamination might come from, laboratory apparatus which have not been cleaned properly or the chemical which have been used to clean the laboratory apparatus. The blank solution for this study was distilled water added with 70% concentration of Nitric acid. This blank solution is done this way because the water samples have been added 70% concentration of Nitric acid, as a preservative to avoid contamination. Referring to the Table 4.1 in Chapter 4, it shows that there was no concentration value for all of the metals tested. This shows the laboratory apparatus and other chemical substances do not contaminate the samples. Good laboratory practices can affect the cleanliness of the laboratory apparatus. Therefore, the water samples will not be affected.

5.1.2 Standard solution

Generally, standard solution is prepared in order to determine the accuracy of the AAS machine in analyzing the heavy metals concentration. Normally, standard solutions are prepared within the range of 0.5 ppm up to 15 ppm. However, for analyzing the water samples, the range that was prepared was between 0.5 ppm to 3ppm. The standard solution, which have been prepared were tested and the calibration slope values that was produced determined the accuracy of the AAS machine. If the calibration slope value is nearly 1.000, therefore the AAS machine, which is used, for analysis is accurate in detecting metals in the drinking water samples. The analyzing of standard solution was done each time before analyzing the water samples. Referring to Table 4.2 in chapter 4, the table shows the calibration slope values. The efficiency of the machine ranged from 0.9576 to 0.9990. The values that were produced were close to 1.000 values. Therefore, the machine is partially accurate and the metals concentration values that the AAS machine detects can be still accepted.

5.2 Metals

The availability and concentration of metals in the drinking water is very much influenced by biotic, abiotic components and also piping system. These factors may also contribute to the variation values of the metals.

The presences of the eight metals are proving to be positive and available in all water samples taken. In this section, the eight metals available were discussed in more detail.

5.2.1 Sodium

The availability of sodium in the water supply especially tap water is caused by the removal of hardness. The levels of sodium can be increased by 1 mg, by removal of 2 mg of hardness (Cohn *et al.*, 1999). Therefore sodium was present in all of the water samples taken from every sampling station.

Based on the results obtained after analyzing the water samples, the values were all below the range based on the WHO Guidelines for Drinking Water Quality 1993/1996. The standards range for sodium in drinking water, was 200 mg/L. The lowest mean value of sodium concentration based on Figure 4.1 in Chapter 4 was, 1.182 mg/L for station 6 while the highest mean value of sodium concentration was 1.799 mg/L for station 3. Station 3 represents KK1 Tank while station 6 represents KK2 Pipe.

Statistical analysis was done to compare each stations mean value. Based on the analysis which, mean values between station 6 with station 1, 2, 4, and 5 were not significant. This shows that the values for station 1, 2, 4, 5 and 6 were the same and they were no variation from each other. This situation happens most probably because the accumulation of sodium in each station stated were evenly distributed. However there was a significant difference between station 3 and station 6. This happens probably because the accumulation of salts in station 3 and station 6 differ greatly from each other, with mean values of 1.937 mg/L and 1.182 mg/L respectively. The KK1 Water Tank samples were taken from the pipe, which attached to the bottom of the tank. This is where the accumulation of salts could have been greater at the bottom than the other parts of the tank. That is why the concentration level of sodium in the water samples taken from this area was higher compared to samples from KK2 Pipe. The accumulation in KK2 Pipe however, was lower in value because, the water supply through that piping was constantly running, as it was used for the main activity in that area which was cooking. The results of the statistical analysis could be found on Appendix B1 for multiple comparison result.

5.2.2 Calcium

Hard water contains excessive concentrations of calcium (Logsdon *et al*., 1999). The water, which was taken in for processing at the LAKU Water Treatment Plant, was surface water, which was from the Sibiu River. Surface water can be treated by precipatative lime softening to remove hardness. Treatment involves adding hydrated lime to water to raise pH sufficiently to precipitate calcium. However, water hardness could not be totally diminished from the water supply. Calcium in the form of calcium carbonate may also still present in the water. That is why calcium is present in all water samples taken from all sampling stations.

Based on Figure 4.2, the lowest mean value of calcium concentration was 0.417 mg/L at station 5, while the highest mean value was 4.124 mg/L at station 2. Station 2 represents for LAKU Water Tank and station 5 represents for KK2 Water Tank. All of the mean calcium values for each station below the standard value based on the WHO Guidelines for Drinking Water Quality 1984. The standards range for calcium in drinking water, was 500 mg/L.

Based on statistical analysis, comparisons of mean values between stations 1, 3, 4, and 6 mostly were not significant. This shows that the value between these stations does not differ and assumed that the calcium at the stations was evenly distributed. However for between station 2 and station 5 the mean difference was significant. Based on the Figure 4.2, the bar graph clearly shows that the calcium concentration for station 2 was higher compared to station 5. Station 2 and station 5 calcium concentrations were 4.124 mg/L and 0.417 mg/L respectively. The difference in concentration was probably contributed to the amount of calcium accumulation at each station. The water inlet pipes could have contributed to the high concentration of calcium at station 2, which was LAKU Water Tank. The water inlet pipes in the LAKU Water Tank were distribution pipes which flows processed water from the LAKU Water Treatment Plant. The inlet pipes were ductile iron pipes and calcium scales may form within the pipes after a long period of time depending on the concentration of calcium. The calcium scales might have been leached out and accumulate in the tank at time of sampling. The water samples from KK2 Water Tank however had low calcium concentration as compared to LAKU Water Tank. This is because, the campus distribution pipeline has been change to High Density Polyethylene (HDPE) pipes quite recently and maybe there were less calcium scales development in the distribution pipelines. The results of the statistical analysis could be found on appendix B1 for overall sodium ANOVA result and appendix C2 for multiple comparison result. The results of the statistical analysis could be found on Appendix B2 multiple comparison result.

5.2.3 Magnesium

Magnesium was present in all water samples taken from all sampling stations. Based on Figure 4.3, the lowest mean copper concentration occur at station 5 with the value of 0.159 mg/L, while the highest mean copper concentration was at station 3 with the value of 0.225 mg/L. Based on the Malaysia Guidelines for Drinking Water Quality 1990, the standard for magnesium concentration was 150 mg/L. The mean values for all station however were below the standard requirement for magnesium concentration in drinking water.

Based on the statistical analysis which was done to compare mean values between stations, the comparison outcome was that all mean differences for all station compared were not significant. This is because; the means values for each station does not vary from each other and were at the same value. It probably happens because the manganese concentration was evenly distributed at all stations. The results of the statistical analysis could be found on appendix B3 for multiple comparison result.

5.2.4 Manganese

Manganese occurs naturally in water. The water samples from every sampling station contain manganese. Based on Figure 4.4, the lowest mean value of manganese concentration was 0.192 mg/L at station 4, while the highest mean value was 0.392 mg/L at station 1. All of the mean values for each station were exceeding the values based on the WHO Guidelines for Drinking Water Quality 1984. The standards range for manganese in drinking water, was 0.1 mg/L. The high level of manganese in these water samples indicates that the soluble manganese metal has undergone oxidation. Oxidation of soluble manganese in distribution systems can cause aesthetic problems such as water discolouration and fouling, staining on plumbing fixtures, and consumer complaints (Sly *et al.*, 1990; Reyes, 2004; Cerrato *et al.*, 2006). This probably was the cause of the water impurity supply in the campus.

Based on statistical analysis, comparisons of mean values for all of the station were not significant. This means that there were no differences between the mean values for each of the stations. The results of the statistical analysis could be found on Appendix B4 for multiple comparison result.

5.2.5 Iron

Iron occurs in water supplies due to water distribution piping or plumbing fixtures. The water sample, which was taken from most station, contains iron. Out of the six stations, only 5 stations had iron elements in the samples collected. Based on Figure 4.5, the lowest mean value was at 0.00 mg/L, which was considered as none, occurring at station 1. The highest mean value was 1.447 mg/L for station 3. The mean values for station 3 and station 5 were exceeding the values based on the WHO Guidelines for Drinking Water Quality 1993/1996. The standard given was 0.3 mg/L of iron concentration. The mean iron concentration for station 3 and station 5 were 1.447 mg/L and 0.329 mg/L. However, the amount of exceeding will probably only effect the water aesthetically as it will give a bitter astringent taste to water.

Based on statistical analysis, comparison of mean values between station 3 with stations 2, 4, 5, 6 were significant. The rest of the comparisons between stations were not significant. The concentration of iron differs at station 3 and station 2 mainly caused by plumbing fixtures. At station 2 (LAKU Water Tank), the iron mean concentration value was 0.160 mg/L while at station 3 (KK1 Tank) was 1.447 mg/L. There was a rise of iron concentration from station 2 to station 3. At station 2, the concentration of iron in the water, could have been low because the tank was wide and accumulation at that sampling point might have been low. However, water samples that were taken from station 3 were high because the iron could have come from the iron piping. The pipe itself was a galvanized iron pipe and has undergone weathering, and rust from iron pipes can increase the dissolve concentration of iron in the processed water (Cohn *et al.*, 1999). There was a huge decrease of mean iron concentration from station 3 to station 4 and station 6. This is because; there was less accumulation of iron at station 4 and 6, as station 4 was KK1 Pipe and station 6 was KK2 Pipe. This pipe was constantly running, as this area was the cafeteria where cooking activities were done and water usage was constantly moving around the clock. Iron concentration will be lesser after the first flush of water running out from the pipe. Sampling was done later in the day after the cafeteria was open. Between station 3 and station 5, the mean values were also decreasing even though the stations were similar in construction. Station 5 was KK2 Water Tank. The decrease in level could not be proved at this moment. However the probability could have been because of less accumulation of iron or less iron scales development within the pipe, which was attached to the KK2 Water Tank. The results of the statistical analysis could be found on Appendix B5 for multiple comparison result.

5.2.6 Zinc

Zinc occurs in all water samples taken from every station. Based on Figure 4.6, the lowest amount or mean zinc concentration was 0.442 mg/L at station 5, whereas the highest amount was at station 2 with mean zinc concentration of 0.852 mg/L. Based on the WHO Guidelines for Drinking Water Quality 1993/1996, the standard for zinc concentration was 3 mg/L. The mean zinc concentrations for all stations were lower compared to the given standard.

Based on statistical analysis, comparison of mean values between most stations (station 1, 3, 4 and 6) were not significant. This is because the mean values were the same for most of the stations. However, there was a mean difference between station 2 and station 5 and was significant. Based on Figure 4.6, station 2 mean zinc concentration was lower compared to station 5. Station 2 has a low concentration of zinc compared to station 5 probably was because the tank was big and the accumulation was not only at that point where sample collecting was done. Station 5 (KK2 Water Tank) was higher in concentration because zinc commonly occurs in water and may leach into processed water through corrosion of galvanized metal pipes (Cohn *et al.* 1999), which was attached to the tank. The distribution pipe within the building were galvanized iron pipe. A study has been done to analyze the composition of iron pipes, which undergo corrosion. The iron material was primarily composed of iron and oxygen which indicates the formation of iron oxides; and the next elements that could be found was chlorine, zinc and lead (Cerrato *et al.*, 2006). Therefore there was a possibility that zinc was leached out into the samples at station 5. The results of the statistical analysis could be found on Appendix B6 for multiple comparison result.

5.7.7 Lead

Lead was present in all water samples taken from all stations. Based on Figure 4.7, the lowest mean lead concentration was 0.196 mg/L for station 1 and the highest mean lead concentration was 0.685 mg/L for station 5. Based on the WHO Drinking Water Guidelines 1993/1996, the standard concentration for lead was 0.01mg/L. Comparing all the stations mean value with the standard concentration given, all of the values exceeded the limits. Plumbing materials could have caused the availability of lead in the water samples.

Based on statistical analysis, comparisons of mean values between stations were not significant between stations 2 and 3, 2 and 4, 2 and 6, 3 and 6, 4 and 6, and between 5 and 6. This happens because the lead concentrations between these stations were the same. However the comparisons, which were significant, were between station 1 with stations 2, 3, 4, 5, and 6. Besides that the comparison between station 5 with stations 2, 3 and 4 were also significant. Based on Figure 4.7, station 1 has the least mean lead concentration compared to the other stations. There was a rise in mean lead concentration from station 1 to station 2. This shows that probably the accumulation of lead was higher in the water storage in the tank, as compared to the water supply from the distribution pipeline. The cause of this factor not be identify as yet. Further study is needed to analyze the factors, which cause this.

The significant outcome from the comparison between station 1 to stations 3, 4, 5, and 6 could be concluded that the plumbing fixtures probably cause it. The lead concentration at the pipe (tap) depend not only on the corrosion rate but also the number of leaded joints in the plumbing, the area of solder exposed to water at each joint, and the water usage pattern (Gregory, 1990; Hoven *et al.*, 2006). The distribution pipes, which distribute the water to KK1 Water Tank (station 3) and also KK2 Water Tank (station5), were galvanized iron pipes. The amount of lead, which was released, from these pipes, was greater than station 1. This was because the galvanized iron pipes can contain up to 1 % lead (Leroy, 1993; Hoven *et al.*, 2006). The galvanized iron pipes can get corrosion after sometime, and the composition of the pipes, which includes lead, will leach out under strong currents of water. Station 4 and station 6 mean concentrations values were higher than station 1 were also because of the exposure of solder of the plumbing joints to water.

The comparison between station 5 to station 2, 3 and 4 were significant. Based on Figure 4.7, the mean concentration value for station 2, 3 and 4 are lower than station

5. However, the causes of these significant mean values were also contributed by the plumbing problems. The high concentration of lead may pose a health threat to the water supply consumers of this campus. Such health threats are for example, kidney damage, impaired cognitive performance, delayed neurological development and elevated high blood pressure. However, further investigation is needed to look into this matter. The results of the statistical analysis could be found on Appendix B7 for multiple comparison result.

5.7.8 Copper

Copper was present in all water samples taken from all sampling stations. Based on Figure 4.8, the lowest mean copper concentration occur at station 6 with the value of 0.049, while the highest mean copper concentration was at station 5 with the value of 0.009 mg/L. Based on the WHO Guidelines for Drinking Water Quality 1984, the standard for copper concentration was 1 mg/L. The mean copper concentrations for all stations were lower compared to the given standard.

Based on the statistical analysis which was done to compare mean values between stations, the comparison outcome was that all mean differences for all station compared were not significant. This probably happens because the copper concentration was not high at sampling time and thy were no variation between the station. The results of the statistical analysis could be found on Appendix B8 for multiple comparison result.

CHAPTER 6

CONCLUSION

As a whole, this study has succeeded in achieving the objectives of this study. The eight metals, which were analyzed, were present in all of the water samples from every sampling station. This shows that the water supply of Universiti Putra Malaysia, Bintulu Campus is not clean and contains several metals, which are also dangerous in the long run to consumers. Out of the eight metals analyzed, three types of metals were exceeding the standard requirements based on WHO and Malaysia Guidelines for Drinking Water. The metals are manganese, iron and lead. Among these three metals, lead is the most dangerous elements found in the water supply. The rest of the metals such as sodium, calcium, magnesium, zinc and copper were below the standard requirements and are at a safe concentration value. Plumbing materials and the cleanliness of water storage tanks cause the metal pollution, which causes water impurities in the water supply of this campus. Plumbing fixtures, which are made of iron, could contribute to the availability of certain metals such as copper, iron and lead. This is because the iron pipes are made of lead, copper and also iron. Therefore, the plumbing fixtures and distribution water pipelines within a building should be change to avoid metal pollution. Besides that, the water storage tanks especially LAKU Water Tank, should be monitored and clean frequently to avoid high accumulation of metals in the water supply. However, further study is required to investigate into this matter to find out more on the factors that trigger the availability of metals in the water supply of Universiti Putra Malaysia Bintulu Campus.

REFERENCES

Agarwal, S.K., Tiwari, S.C. and Dash, S.C. 1993. Spectrum of poisoning requiring hemodialysis in a tertiary care hospital in India. *International Journal of Artificial Organs.* **16(1):** 20–22.

Anderson, T.W., Neri, L.C., Schreiber, G.B., Talbot, F.D. and Zdrojewski, A. 1975. Ischemic heart disease, water hardness and myocardial magnesium. *Canadian Medical Association Journal.* **113**:119-203.

ATSDR. 2002. *Toxicological profile for copper*. US Department of Health and Human Services, Public Health Service. Agency for Toxic Substances and Disease Registry.

ATSDR, 2000. *Toxicological profile for manganese.* US Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry. Atlanta, GA.

Bartram, J. and Balance, R. 1996. *Water Quality Monitoring* : A Practical Guide to the Design and Implementation of Freshwater Quality Studies and Monitoring Programmes. London: E and F.N Spon,

Barceloux, D.G. 1999. Manganese. *Clinical Toxicology*. **37:** 293–307.

Bound, J.P., Harvey, P.W., Brookes, D.M. and Sayers, B.M. 1981. The incidence of anencephalus in the Fylde Peninsula 1956–1976 and changes in water hardness. *Journal of Epidemiology and Community Health.* **35(2)**:102-105.

Bothwell, T.H., Charlton, R.W., Cook, J.D. and Finch, C.A. 1979. Iron metabolism in man. Blackwell: Oxford

Cerrato, J.M., Reyes, L.P., Alvarado, C.N. and Dietrich, A.M., 2006. Effect of PVC and iron materials on Mn(II) deposition in drinking water distribution systems. *Journal of Water Research.* **40:**2720-2726.

Cohen, J.M., Kamphake, L.J., Harris, E.K. and Woodward, R.L. 1960. Taste threshold concentrations of metals in drinking water. *Journal of the American Water Works Association.* **52:** 660.

Cohn, P.D., Cox, M. and Berger, P.S. 1999. Health and aesthetics aspects of water quality. In: Letterman, R.D. (ed.). *Water Quality and Treatment; A Handbook of Communities Water Supplies*. American Water Works Association. USA: Mc-Graw Hill Inc. **2**:2.29, 2.32, 2.33.

Crawford, M.D, Gardner, M.J. and Sedgwick, P.A., 1972. Infant mortality and hardness of local water supplies. **1(758)**:988-992. Lancet.

Cosgrove, E., Brown, M.J., Madigan, P., McNulty, P., Okonski, L. and Schmidt, J. 1989. Childhood lead poisoning: case study traces source to drinking water. *Journal of Environmental Health.* **52:** 346.

DNHWC. 1990. *Nutrition recommendations. The report of the Scientific Review Committee*. Department of National Health and Welfare Canada.

Devasia, L. 2002. Rural development with Special emphasis on Woman, Water and Environment. In: Kunst, S., Kruse T. and Burmester, A. (eds.). *Sustainable Water and Soil Management*. Germany: Springer-Verlag Berlin Heidelberg. p.31

Elton, N.W., Elton W.J. and Narzareno J.P. 1963. Pathology of acute salt poisoning in infants: *American Journal of Clinical Pathology*. 39:252-264.

Elinder, C.G., 1986: Zinc. In: Friberg, L., Nordberg, G.F. and Vouk, V.B. (eds.). *Handbook on the toxicology of metals*. Amsterdam: Elsevier Science Publishers. p.664-679

APHA. 1985. *Standard Methods For the Examination of Water and Wastewater*, 16th American Public Health Association, American Water Works Association and Water Pollution Control Federation. Washington DC. Part 300.

Gregory, R. 1990. Galvanic corrosion of lead solder in copper pipework. *Journal Institution of Water and Environmental Management*. **4(2)**:112-118

Hashemi, P. 2000. Major metals. In: Nollet, L.M.L. (ed.). *Handbook of Water Analysis*. Marcel Dekker Inc. **21**:409.

Hoven, T.V.D., and Slaats, N. 2006. Lead Monitoring. In: Quevauviller, P. and Thompson, K.C. (eds.). *Analytical Methods for Drinking Water:Advances in Sampling and Analysis*. England: John Wiley & Sons, Ltd. **3**:64-67

Jantsch, W., Kulig, K and Rumack, B.H. 1984. Massive copper sulfate ingestion resulting in hepatotoxicity. *Journal of Toxicology-Clinical Toxicology.* **22(6):**585-588.

Kawamura, R. 1941. Intoxication by manganese in well water: *Kitasato Archives of Experimental Medicine.* **18:**145–169.

Knobeloch, L., Ziarnik, M., Howard, J., Theis, B., Farmer, D., Anderson, H. and Proctor, M. 1994. Gastrointestinal upsets associated with ingestion of copper-contaminated water. *Environmental Health Perspectives.* **102(11):** 958–961.

Leroy, P. 1993. Lead in drinking water- origins, solubility, treatment. *Journal Water SRT-Aqua.* **42(4):**233-238.

Levin, R., Schock. M.R. and Marcus, A.H. 1989. Exposure to lead in U.S. drinking water. *Proceedings of the 23rd Annual Conference on Trace Substances in Environmental Health.* Cincinnati, OH: US Environmental Protection Agency,

Logsdon, G., Hess, A. and Horsley M. 1999. Guide to selection of water treatment process. In: Letterman, R.D. (ed.). *Water Quality and Treatment: A Handbook of communities water supplies.* American Water Works Association. USA: Mc-Graw Hill Inc. **3:**3.20.

Low, B.A., Donohue, J.M. and Bartley, C.B. 1996. Backflow prevention failures and copper poisonings associated with post-mix soft drink dispensers. Ann Arbor, Michigan: NSF International.

Moore, M.R., Goldberg, A., Fyfe, W.M. and Richards, W.N. 1981. Maternal lead levels after alterations to water supply. *Lancet.* **2:**203-204.

Marier, J,R, Neri, L.C. and Anderson, T.W. 1979. Water hardness, human health, and the importance of magnesium. Ottawa: National Research Council of Canada.

NAS. 1980. *Drinking Water and Health.* National Academy of Science. Vol. 3. Washington, DC, National Academy Press. p.283-293.

NRC. 1979. *Iron.* National Research Council. Baltimore, University Park Press.

Nriagu, J.O. 1980. Zinc in the environment: *Ecological cycling.* Part 1. New York: John Wiley.

Olivares, M. and Uauy, R. 1996. Limits of metabolic tolerance to copper and biological basis for present recommendations and regulations. *American Journal of Clinical Nutrition*. **63:**846S–852S.

Pathak, D. 2002. Rural development with Special emphasis on Woman, Water and Environment. In: Kunst, S., Kruse, T. and Burmester, A (eds.). *Sustainable Water and Soil Management*. Germany: Springer-Verlag. p.57.

Quinn, M.J. and Sherlock, J.C. 1990. The correspondence between U.K. 'action levels' for lead in blood and in water. *Food additives and contaminants*. **7:** 87-424.

Reyes, L. 2004. *Investigation of the Incrusting Aspect of Manganese Oxide on the Potable Water Pipes of the Aqueducts of Tegucigalpa and Cormayaguela.* National Autonomous Service of Aqueducts and Sewages of Honduras. p.4.

Schock, M.R. 1989. Understanding lead corrosion control strategies. *Journal of the American Water Works Association.* **81:** 88.

Sherlock, J.C., Ashby, D., Delves, H.T., Forbes, G.I., Moore, M.R., Patterson, W.J., Pocock, S.J., Quinn, M.J., Ricahrd, W.N. and Wilson, T.S. 1984. Reduction in exposure to lead from drinking water and its effect on blood lead concentrations. *Human Toxicology.* **3:** 383-392.

Sly, L., Hodgekinson, M. and Arunpairojana, V. 1990. Deposition of managanese in a drinking water distribution system. *Applied Environment Microbiology.* **56(3):** 628-639.

Spitalny, K.C., Brondum, J., Vogt, R.L., Sargent, H.E. and Kappel, S. 1984. Drinking-water-induced copper intoxication in a Vermont family. *Pediatrics.* **74(6):** 1103–1106.

Stenhammar, L. 1999. Diarrhoea following contamination of drinking water with copper. *European Journal of Medical Research.* **4:** 217–218.

Tamasi, G. and Cini, R. 2004. Heavy metals in drinking water from Mount Amiata (Tuscany, Italy). Possible risk from arsenic for public health in the Province of Sienna. *Journal of Science of the Total Environment.* **327:**41-45

WHO. 2003g. Sodium in Drinking-water: *Background document for development of WHO Guidelines for Drinking-water Quality.* Geneva: World Health Organization.

WHO. 2003a. Calcium in Drinking-water: *Background document for development of WHO Guidelines for Drinking-water Quality.* Geneva: World Health Organization.

WHO. 2003e. Magnesium in Drinking-water: *Background document for development of WHO Guidelines for Drinking-water Quality.* Geneva: World Health Organization.

WHO. 2003f. Manganese in Drinking-water: *Background document for development of WHO Guidelines for Drinking-water Quality.* Geneva: World Health Organization.

WHO. 2003c. Iron in Drinking-water: *Background document for development of WHO Guidelines for Drinking-water Quality.* Geneva: World Health Organization.

WHO. 2003h. Zinc in Drinking-water: *Background document for development of WHO Guidelines for Drinking-water Quality.* Geneva: World Health Organization.

WHO. 2003d. Lead in Drinking-water: *Background document for development of WHO Guidelines for Drinking-water Quality.* Geneva: World Health Organization.

WHO. 2004b. Copper in Drinking-water: *Background document for development of WHO Guidelines for Drinking-water Quality.* Geneva: World Health Organization

Wyllie, J. 1957. Copper poisoning at a cocktail party. *American Journal of Public Health.* **47:** 617.

Wigle, D.T., Mao, Y., Semenciw, R. and Smith, M.H. 1986. Contaminants in drinking water and cancer risks in Canadian cities. *Canadia Journal of Public Health.* **77(5)**:335-342.

Zacarias, I., Carmen G.Y., Magdalena A., Chinwe, O. Manuel, O. and Ricardo, U. 2001. Determination of the taste threshold of copper in water. *Chemical Sense.* **26(1):** 85–89.

APPENDIX

A1

METALS CONCENTRATIONS

a) **Mean sodium concentration for three sampling dates (13/10/06, 20/10/06 and 27/10/06) in water samples**

Sodium concentration (mg/L)					
Station 1	Station 2	Station3	Station 4	Station 5	Station 6
1.569±0.571	1.451±0.259	1.779±0.493	1.754±0.714	1.232±0.517	1.182±0.197

b) **Mean calcium concentration for three sampling dates (13/10/06, 20/10/06 and 27/10/06) in water samples**

Calcium concentration (mg/L)					
Station 1	Station 2	Station3	Station 4	Station 5	Station 6
2.796±2.470	4.124±2.603	2.055±1.817	2.643±2.397	0.417±0.182	3.454±2.651

c) **Mean magnesium concentration for three sampling dates (13/10/06, 20/10/06 and 27/10/06) in water samples**

Magnesium concentration (mg/L)					
Station 1	Station 2	Station3	Station 4	Station 5	Station 6
0.171±0.058	0.189±0.047	0.225±0.063	0.165±0.052	0.159±0.026	0.169±0.030

APPENDIX

A2

d) Mean manganese concentration for three sampling dates (13/10/06, 20/10/06 and 27/10/06) in water samples

Manganese concentration (mg/L)					
Station 1	Station 2	Station3	Station 4	Station 5	Station 6
0.392±0.110	0.386±0.054	0.249±0.167	0.192±0.164	0.363±0.159	0.374±0.326

e) Mean iron concentration for three sampling dates (13/10/06, 20/10/06 and 27/10/06) in water samples

Iron concentration (mg/L)					
Station 1	Station 2	Station3	Station 4	Station 5	Station 6
0.000±0.000	0.160±0.072	1.447±1.220	0.064±0.021	0.329±0.202	0.006±0.003

f) Mean zinc concentration for three sampling dates (13/10/06, 20/10/06 and 27/10/06) in water samples

Zinc concentration (mg/L)					
Station 1	Station 2	Station3	Station 4	Station 5	Station 6
0.517±0.268	0.442±0.154	0.589±0.271	0.590±0.260	0.852±0.367	0.503±0.260

APPENDIX

A3

g) Mean lead concentration for three sampling dates (13/10/06, 20/10/06 and 27/10/06) in water samples

Lead concentration (mg/L)					
Station 1	Station 2	Station3	Station 4	Station 5	Station 6
0.196±0.059	0.436±0.134	0.421±0.057	0.425±0.015	0.685±0.098	0.618±0.202

h) Mean copper concentration for three sampling dates (13/10/06, 20/10/06 and 27/10/06) in water samples

Copper concentration (mg/L)					
Station 1	Station 2	Station3	Station 4	Station 5	Station 6
0.005±0.002	0.0050±0.003	0.006±0.006	0.006±0.005	0.049±0.002	0.009±0.007

APPENDIX

B1

MULTIPLE COMPARISON

a) Sodium

Multiple Comparisons

Dependent Variable: Sodium

	(I) Stations	(J) Stations	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	1	2	.11800	.23404	.996	-.5779	.8139
		3	-.36743	.24125	.652	-1.0847	.3498
		4	-.18489	.23404	.968	-.8807	.5110
		5	.33767	.23404	.701	-.3582	1.0335
		6	.38769	.24125	.598	-.3296	1.1050
	2	1	-.11800	.23404	.996	-.8139	.5779
		3	-.48543	.24125	.351	-1.2027	.2318
		4	-.30289	.23404	.787	-.9987	.3930
		5	.21967	.23404	.934	-.4762	.9155
		6	.26969	.24125	.871	-.4476	.9870
	3	1	.36743	.24125	.652	-.3498	1.0847
		2	.48543	.24125	.351	-.2318	1.2027
		4	.18254	.24125	.973	-.5347	.8998
		5	.70510	.24125	.057	-.0122	1.4224
		6	.75513*	.24824	.042	.0171	1.4932
	4	1	.18489	.23404	.968	-.5110	.8807
		2	.30289	.23404	.787	-.3930	.9987
		3	-.18254	.24125	.973	-.8998	.5347
		5	.52256	.23404	.243	-.1733	1.2184
		6	.57258	.24125	.187	-.1447	1.2899
	5	1	-.33767	.23404	.701	-1.0335	.3582
		2	-.21967	.23404	.934	-.9155	.4762
		3	-.70510	.24125	.057	-1.4224	.0122
		4	-.52256	.23404	.243	-1.2184	.1733
		6	.05003	.24125	1.000	-.6672	.7673
	6	1	-.38769	.24125	.598	-1.1050	.3296
		2	-.26969	.24125	.871	-.9870	.4476
		3	-.75513*	.24824	.042	-1.4932	-.0171
		4	-.57258	.24125	.187	-1.2899	.1447
		5	-.05003	.24125	1.000	-.7673	.6672

*. The mean difference is significant at the .05 level.

APPENDIX

B2

MULTIPLE COMPARISON

b) Calcium

Multiple Comparisons

Dependent Variable: Calcium

	(I) Stations	(J) Stations	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	1	2	-1.32811	1.03484	.792	-4.4108	1.7546
		3	.74111	1.03484	.979	-2.3416	3.8238
		4	.15264	1.06669	1.000	-3.0250	3.3302
		5	2.37914	1.06669	.245	-.7985	5.5567
		6	-.65783	1.10629	.991	-3.9534	2.6377
	2	1	1.32811	1.03484	.792	-1.7546	4.4108
		3	2.06922	1.03484	.359	-1.0135	5.1519
		4	1.48075	1.06669	.734	-1.6968	4.6583
		5	3.70725*	1.06669	.014	.5297	6.8848
		6	.67029	1.10629	.990	-2.6253	3.9659
	3	1	-.74111	1.03484	.979	-3.8238	2.3416
		2	-2.06922	1.03484	.359	-5.1519	1.0135
		4	-.58847	1.06669	.994	-3.7661	2.5891
		5	1.63803	1.06669	.644	-1.5396	4.8156
		6	-1.39894	1.10629	.802	-4.6945	1.8966
	4	1	-.15264	1.06669	1.000	-3.3302	3.0250
		2	-1.48075	1.06669	.734	-4.6583	1.6968
		3	.58847	1.06669	.994	-2.5891	3.7661
		5	2.22650	1.09762	.343	-1.0432	5.4962
		6	-.81046	1.13614	.979	-4.1949	2.5740
	5	1	-2.37914	1.06669	.245	-5.5567	.7985
		2	-3.70725*	1.06669	.014	-6.8848	-.5297
		3	-1.63803	1.06669	.644	-4.8156	1.5396
		4	-2.22650	1.09762	.343	-5.4962	1.0432
		6	-3.03696	1.13614	.101	-6.4214	.3475
	6	1	.65783	1.10629	.991	-2.6377	3.9534
		2	-.67029	1.10629	.990	-3.9659	2.6253
		3	1.39894	1.10629	.802	-1.8966	4.6945
		4	.81046	1.13614	.979	-2.5740	4.1949
		5	3.03696	1.13614	.101	-.3475	6.4214

*. The mean difference is significant at the .05 level.

APPENDIX

B3

MULTIPLE COMPARISON

c) Magnesium

Multiple Comparisons

Dependent Variable: Magnesium

	(I) Stations	(J) Stations	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	1	2	-.02433	.02258	.888	-.0914	.0427
		3	-.06056	.02258	.098	-.1276	.0065
		4	.00033	.02258	1.000	-.0667	.0674
		5	.00589	.02258	1.000	-.0611	.0729
		6	-.00433	.02258	1.000	-.0714	.0627
	2	1	.02433	.02258	.888	-.0427	.0914
		3	-.03622	.02258	.600	-.1032	.0308
		4	.02467	.02258	.882	-.0424	.0917
		5	.03022	.02258	.762	-.0368	.0972
		6	.02000	.02258	.948	-.0470	.0870
	3	1	.06056	.02258	.098	-.0065	.1276
		2	.03622	.02258	.600	-.0308	.1032
		4	.06089	.02258	.095	-.0061	.1279
		5	.06644	.02258	.053	-.0006	.1335
		6	.05622	.02258	.148	-.0108	.1232
	4	1	-.00033	.02258	1.000	-.0674	.0667
		2	-.02467	.02258	.882	-.0917	.0424
		3	-.06089	.02258	.095	-.1279	.0061
		5	.00556	.02258	1.000	-.0615	.0726
		6	-.00467	.02258	1.000	-.0717	.0624
	5	1	-.00589	.02258	1.000	-.0729	.0611
		2	-.03022	.02258	.762	-.0972	.0368
		3	-.06644	.02258	.053	-.1335	.0006
		4	-.00556	.02258	1.000	-.0726	.0615
		6	-.01022	.02258	.997	-.0772	.0568
	6	1	.00433	.02258	1.000	-.0627	.0714
		2	-.02000	.02258	.948	-.0870	.0470
		3	-.05622	.02258	.148	-.1232	.0108
		4	.00467	.02258	1.000	-.0624	.0717
		5	.01022	.02258	.997	-.0568	.0772

APPENDIX

B4

MULTIPLE COMPARISON

d) Manganese

Multiple Comparisons

Dependent Variable: Manganese

	(I) Station	(J) Station	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	1	2	.00633	.08688	1.000	-.2522	.2649
		3	.14382	.08956	.599	-.1227	.4103
		4	.20082	.08956	.239	-.0657	.4673
		5	.02907	.08956	.999	-.2375	.2956
		6	.01833	.08688	1.000	-.2402	.2769
	2	1	-.00633	.08688	1.000	-.2649	.2522
		3	.13749	.08956	.644	-.1290	.4040
		4	.19449	.08956	.271	-.0720	.4610
		5	.02274	.08956	1.000	-.2438	.2893
		6	.01200	.08688	1.000	-.2466	.2706
	3	1	-.14382	.08956	.599	-.4103	.1227
		2	-.13749	.08956	.644	-.4040	.1290
		4	.05700	.09216	.989	-.2173	.3313
		5	-.11475	.09216	.812	-.3890	.1595
		6	-.12549	.08956	.726	-.3920	.1410
	4	1	-.20082	.08956	.239	-.4673	.0657
		2	-.19449	.08956	.271	-.4610	.0720
		3	-.05700	.09216	.989	-.3313	.2173
		5	-.17175	.09216	.437	-.4460	.1025
		6	-.18249	.08956	.338	-.4490	.0840
	5	1	-.02907	.08956	.999	-.2956	.2375
		2	-.02274	.08956	1.000	-.2893	.2438
		3	.11475	.09216	.812	-.1595	.3890
		4	.17175	.09216	.437	-.1025	.4460
		6	-.01074	.08956	1.000	-.2773	.2558
	6	1	-.01833	.08688	1.000	-.2769	.2402
		2	-.01200	.08688	1.000	-.2706	.2466
		3	.12549	.08956	.726	-.1410	.3920
		4	.18249	.08956	.338	-.0840	.4490
		5	.01074	.08956	1.000	-.2558	.2773

APPENDIX

B5

MULTIPLE COMPARISON

e) Iron

Multiple Comparisons

Dependent Variable: Iron

	(I) Station	(J) Station	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	2	3	-1.28646*	.31269	.004	-2.2142	-.3587
		4	.09594	.31269	.998	-.8318	1.0237
		5	-.16911	.27638	.972	-.9891	.6509
		6	.15414	.42817	.996	-1.1162	1.4245
	3	2	1.28646*	.31269	.004	.3587	2.2142
		4	1.38240*	.33775	.004	.3803	2.3845
		5	1.11735*	.30444	.011	.2141	2.0206
		6	1.44060*	.44680	.029	.1150	2.7662
	4	2	-.09594	.31269	.998	-1.0237	.8318
		3	-1.38240*	.33775	.004	-2.3845	-.3803
		5	-.26505	.30444	.905	-1.1683	.6382
		6	.05820	.44680	1.000	-1.2674	1.3838
	5	2	.16911	.27638	.972	-.6509	.9891
		3	-1.11735*	.30444	.011	-2.0206	-.2141
		4	.26505	.30444	.905	-.6382	1.1683
		6	.32325	.42218	.938	-.9294	1.5759
	6	2	-.15414	.42817	.996	-1.4245	1.1162
		3	-1.44060*	.44680	.029	-2.7662	-.1150
		4	-.05820	.44680	1.000	-1.3838	1.2674
		5	-.32325	.42218	.938	-1.5759	.9294

*. The mean difference is significant at the .05 level.

APPENDIX

B6

MULTIPLE COMPARISON

f) Zinc

Multiple Comparisons

Dependent Variable: Zinc

	(I) Station	(J) Station	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	1	2	.07489	.12753	.991	-.3036	.4534
		3	-.07256	.12753	.993	-.4510	.3059
		4	-.07278	.12753	.992	-.4513	.3057
		5	-.33522	.12753	.110	-.7137	.0433
		6	.01356	.12753	1.000	-.3649	.3920
	2	1	-.07489	.12753	.991	-.4534	.3036
		3	-.14744	.12753	.855	-.5259	.2310
		4	-.14767	.12753	.854	-.5261	.2308
		5	-.41011*	.12753	.027	-.7886	-.0316
		6	-.06133	.12753	.997	-.4398	.3171
	3	1	.07256	.12753	.993	-.3059	.4510
		2	.14744	.12753	.855	-.2310	.5259
		4	-.00022	.12753	1.000	-.3787	.3783
		5	-.26267	.12753	.325	-.6411	.1158
		6	.08611	.12753	.984	-.2924	.4646
	4	1	.07278	.12753	.992	-.3057	.4513
		2	.14767	.12753	.854	-.2308	.5261
		3	.00022	.12753	1.000	-.3783	.3787
		5	-.26244	.12753	.326	-.6409	.1160
		6	.08633	.12753	.984	-.2921	.4648
	5	1	.33522	.12753	.110	-.0433	.7137
		2	.41011*	.12753	.027	.0316	.7886
		3	.26267	.12753	.325	-.1158	.6411
		4	.26244	.12753	.326	-.1160	.6409
		6	.34878	.12753	.087	-.0297	.7273
	6	1	-.01356	.12753	1.000	-.3920	.3649
		2	.06133	.12753	.997	-.3171	.4398
		3	-.08611	.12753	.984	-.4646	.2924
		4	-.08633	.12753	.984	-.4648	.2921
		5	-.34878	.12753	.087	-.7273	.0297

*. The mean difference is significant at the .05 level.

APPENDIX

B7

MULTIPLE COMPARISON

g) Lead

Multiple Comparisons

Dependent Variable: Lead

	(I) Station	(J) Station	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Tukey HSD	1	2	-.23946*	.06151	.006	-.4265	-.0524
		3	-.22483*	.06493	.018	-.4223	-.0273
		4	-.22813*	.06974	.029	-.4403	-.0160
		5	-.48863*	.05894	.000	-.6679	-.3093
		6	-.42129*	.06151	.000	-.6084	-.2342
	2	1	.23946*	.06151	.006	.0524	.4265
		3	.01463	.06896	1.000	-.1951	.2244
		4	.01133	.07352	1.000	-.2123	.2349
		5	-.24917*	.06336	.006	-.4419	-.0564
		6	-.18183	.06576	.092	-.3818	.0182
	3	1	.22483*	.06493	.018	.0273	.4223
		2	-.01463	.06896	1.000	-.2244	.1951
		4	-.00330	.07640	1.000	-.2357	.2291
		5	-.26380*	.06669	.005	-.4666	-.0610
		6	-.19647	.06896	.077	-.4062	.0133
	4	1	.22813*	.06974	.029	.0160	.4403
		2	-.01133	.07352	1.000	-.2349	.2123
		3	.00330	.07640	1.000	-.2291	.2357
		5	-.26050*	.07139	.012	-.4776	-.0434
		6	-.19317	.07352	.122	-.4168	.0304
	5	1	.48863*	.05894	.000	.3093	.6679
		2	.24917*	.06336	.006	.0564	.4419
		3	.26380*	.06669	.005	.0610	.4666
		4	.26050*	.07139	.012	.0434	.4776
		6	.06733	.06336	.892	-.1254	.2601
	6	1	.42129*	.06151	.000	.2342	.6084
		2	.18183	.06576	.092	-.0182	.3818
		3	.19647	.06896	.077	-.0133	.4062
		4	.19317	.07352	.122	-.0304	.4168
		5	-.06733	.06336	.892	-.2601	.1254

*. The mean difference is significant at the .05 level.

APPENDIX

B8

MULTIPLE COMPARISON

h) Copper

Multiple Comparisons

Dependent Variable: Copper

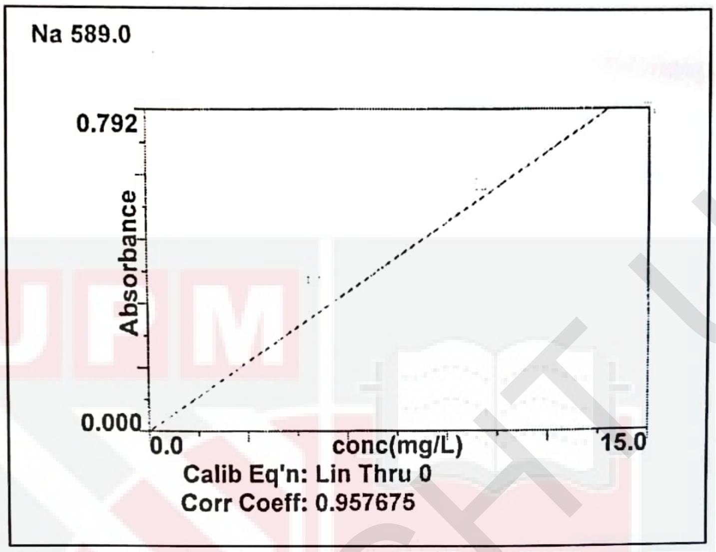
			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
	(I) Station	(J) Station				Lower Bound	Upper Bound
Tukey HSD	1	2	.00000	.00243	1.000	-.0073	.0073
		3	-.00140	.00256	.994	-.0091	.0063
		4	-.00125	.00226	.993	-.0081	.0056
		5	.00013	.00226	1.000	-.0067	.0069
		6	-.00411	.00221	.439	-.0107	.0025
	2	1	.00000	.00243	1.000	-.0073	.0073
		3	-.00140	.00265	.995	-.0094	.0066
		4	-.00125	.00236	.995	-.0083	.0058
		5	.00013	.00236	1.000	-.0070	.0072
		6	-.00411	.00231	.489	-.0110	.0028
	3	1	.00140	.00256	.994	-.0063	.0091
		2	.00140	.00265	.995	-.0066	.0094
		4	.00015	.00249	1.000	-.0073	.0076
		5	.00153	.00249	.990	-.0060	.0090
		6	-.00271	.00244	.874	-.0100	.0046
	4	1	.00125	.00226	.993	-.0056	.0081
		2	.00125	.00236	.995	-.0058	.0083
		3	-.00015	.00249	1.000	-.0076	.0073
		5	.00138	.00219	.988	-.0052	.0079
		6	-.00286	.00213	.758	-.0092	.0035
	5	1	-.00013	.00226	1.000	-.0069	.0067
		2	-.00013	.00236	1.000	-.0072	.0070
		3	-.00153	.00249	.990	-.0090	.0060
		4	-.00138	.00219	.988	-.0079	.0052
		6	-.00424	.00213	.366	-.0106	.0022
	6	1	.00411	.00221	.439	-.0025	.0107
		2	.00411	.00231	.489	-.0028	.0110
		3	.00271	.00244	.874	-.0046	.0100
		4	.00286	.00213	.758	-.0035	.0092
		5	.00424	.00213	.366	-.0022	.0106

APPENDIX

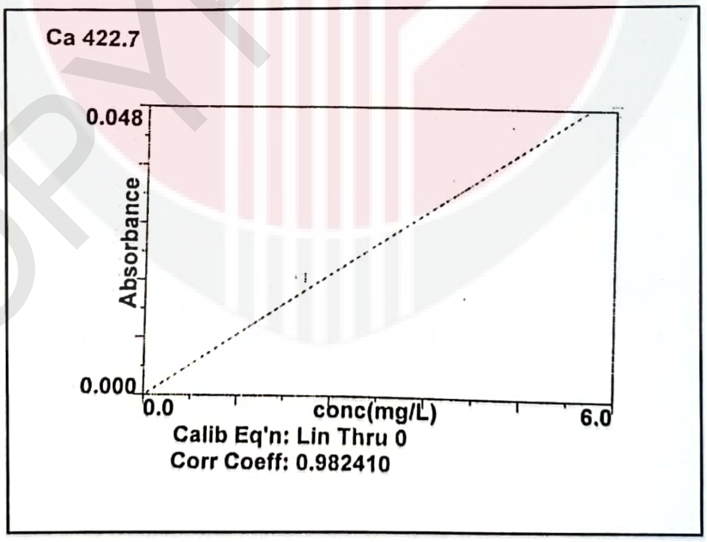
C1

CALIBRATION SLOPE VALUE OF METALS ANALYZED

a) Sodium



b) Calcium

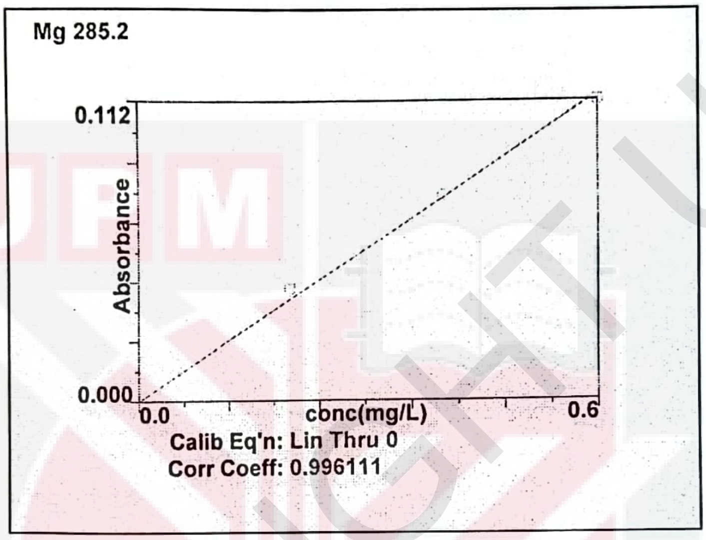


APPENDIX

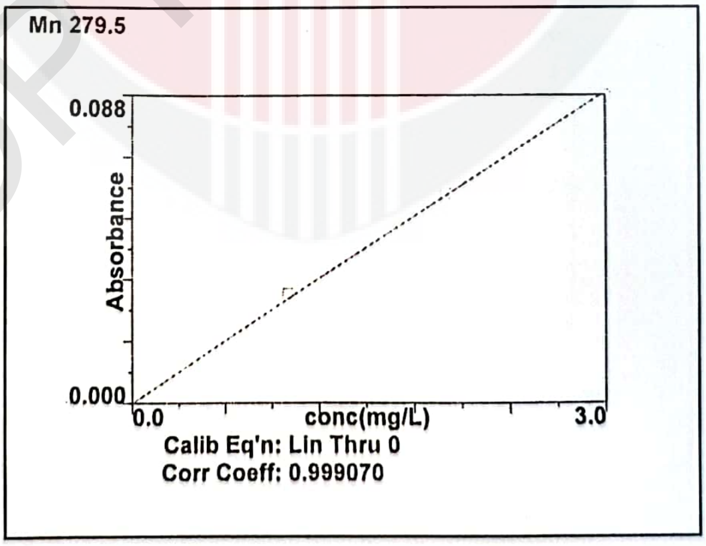
C2

CALIBRATION SLOPE VALUE OF METALS ANALYZED

c) Magnesium



d) Manganese

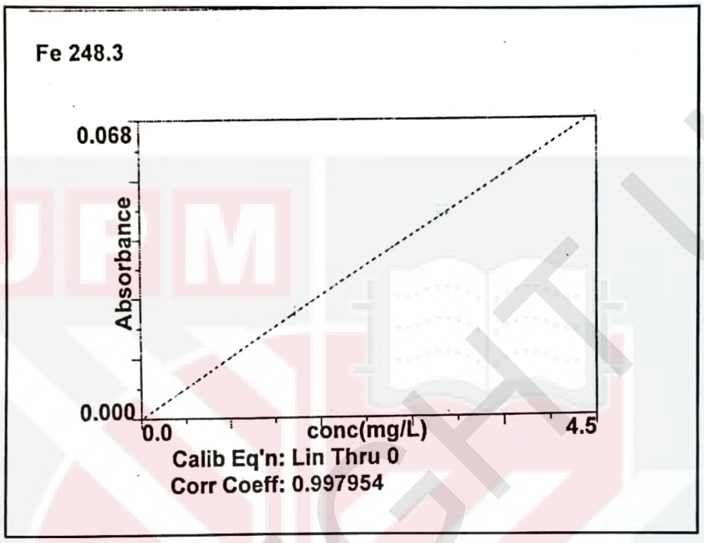


APPENDIX

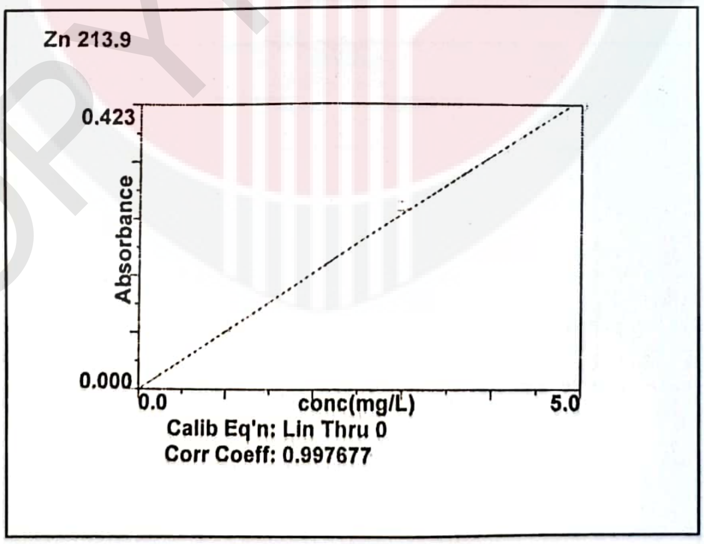
C3

CALIBRATION SLOPE VALUE OF METALS ANALYZED

e) Iron



f) Zinc

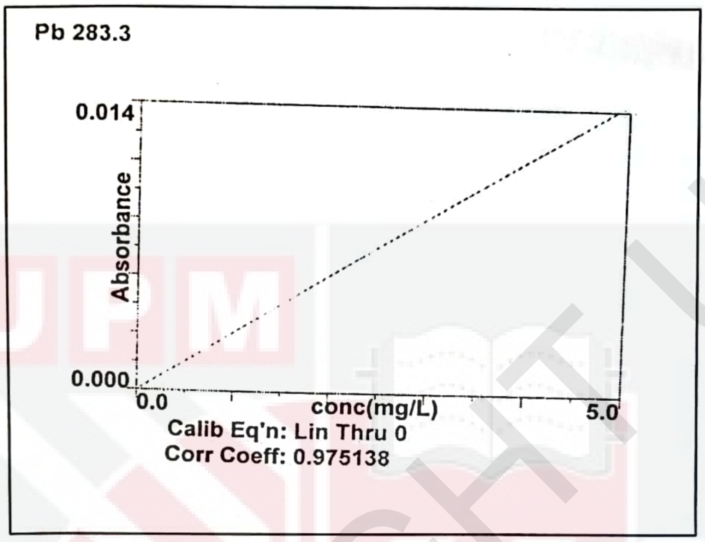


APPENDIX

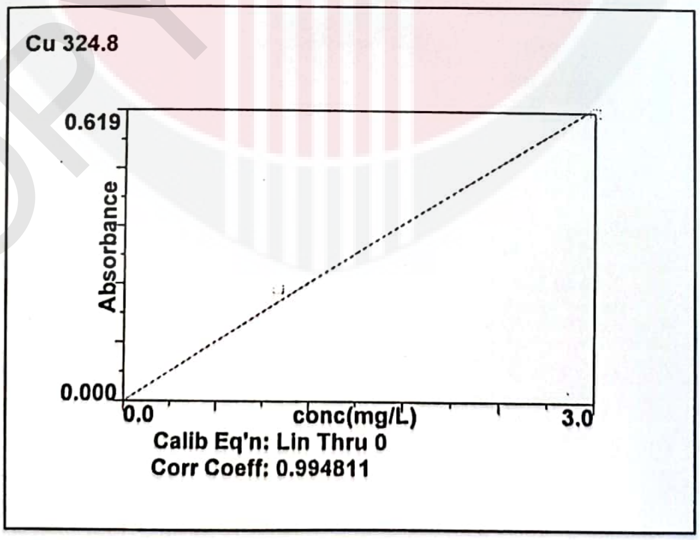
C4

CALIBRATION SLOPE VALUE OF METALS ANALYZED

g) Lead



g) Copper



PUBLICATION OF THE PROJECT UNDERTAKING

This is to certify that I have no objection t publish the project entitled "The Concentration of Metals In Drinking Water of University Putra Malaysia Bintulu Campus " by the supervisor in a joint authorship. However, it has been evaluated by the Faculty of Agriculture and Food Sciences, Universiti Putra Malaysia Bintulu campus and published in the form approved by the Faculty.

……………………………
LOTEZCIA ANAK AJIS

Date : 4th May 2007