# A STUDY ON THE POTENTIAL OF EX-MINING LAKES AS ALTERNATIVE WATER SOURCES.

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# A STUDY ON THE POTENTIAL OF EX-MINING LAKES AS ALTERNATIVE WATER SOURCES

SUHAILA HANI BINTI ABU HAMID

Thesis submitted in partial fulfillment of the requirements
for the award of the degree of
Bachelor of Civil Engineering

Faculty of Civil Engineering and Earth Resources
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JUNE 2015

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"Dedicated to my beloved parents, family and friends"

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## ABSTRACT

Ex-mining lake is not favorable to be utilized as raw water source in Malaysia due to the general perception that water from this body is highly contaminated. The constituent of heavy metals in water from ex-mining lakes is the largest concern in this issue. This report focuses on a study to investigate the potential of water from mining lakes to be used as alternative raw water source for the treatment of domestic and industrial water supply and to observe the most suitable type of coagulant to be used to treat water from ex-mining lakes. In this study, the water samples were extracted from the ex-mining lakes in Bestari Jaya, Selangor. The samples were collected from three (3) different sampling points of the lakes. The lake water samples that came from the mining lakes were analyzed for three different categories of parameters; 1) physical parameter, 2) chemical parameter, 3) microbiological parameter, and tested before and after being treated by two different types of coagulants; Alum and Poly Aluminium Chloride. The physical parameters include the temperature, pH, and turbidity. The Chemical Oxygen Demand (COD), Dissolved Oxygen (DO) and heavy metals were tested under the chemical characteristics. The heavy metals that involved in this study include the Fe, Cu, Mn, Zn, Cl, Cd, and Pb. Finally, the samples were tested for the Total Coliform existence. The results showed that water from ex-mining lakes has high COD values. The concentration of Pb and Cd in the three stations exceeded the limits prescribed by the Ministry of Health (MOH), but can be eliminated using coagulation treatment using Alum and Poly-Aluminium Chloride. Based on the study, it can be concluded that water from ex-mining lakes has the potential in becoming the alternative water source in Malaysia.

## ABSTRAK

Tasik bekas lombong tidak menjadi pilihan utama untuk digunakan sebagai sumber air mentah di Malaysia disebabkan persepsi umum bahawa air dari sumber ini sangat tercemar. Konstituen logam berat dalam air dari tasik bekas lombong menjadi kebimbangan terbesar dalam isu ini. Laporan ini memberi tumpuan kepada kajian untuk menyelidik potensi air dari tasik bekas lombong untuk digunakan sebagai alternatif sumber air mentah bagi sumber bekalan air domestik dan perindustrian selain mengenalpasti jenis koagulan yang paling sesuai untuk digunakan bagi merawat air dari tasik bekas lombong. Dalam kajian ini, sampel air telah diambil dari tasik bekas lombong di Bestari Jaya, Selangor. Sampel telah dikumpulkan dari tiga (3) titik persampelan yang berbeza. Sampel air tasik yang datang dari tasik perlombongan dianalisis bagi tiga kategori yang berbeza, parameter yang terlibat; 1) parameter fizikal, 2) parameter kimia, 3) parameter mikrobiologi, dan sample air ini diuji sebelum dan selepas rawatan oleh dua jenis koagulan; *Alum* dan *Poly-Aluminium Chloride.* Parameter fizikal termasuk suhu, pH, dan kekeruhan. *Chemical Oxygen Demand* (COD), Oksigen Terlarut (DO) dan logam berat telah diuji di bawah ciri-ciri kimia. Logam berat yang terlibat dalam kajian ini termasuk Fe, Cu, Mn, Zn, Cl, Cd dan Pb. Akhir sekali, sampel telah diuji untuk kewujudan Koliform. Hasil kajian menunjukkan bahawa air dari tasik bekas lombong mempunyai nilai COD yang tinggi. Kepekatan Pb dan Cd dalam tiga stesen melebihi had yang ditetapkan oleh Kementerian Kesihatan Malaysia (KKM), tetapi boleh dihapuskan menggunakan proses *coagulation* menggunakan *Alum* dan *Poly-Aluminium Chloride*. Berdasarkan kajian ini, dapat disimpulkan bahawa air dari tasik bekas lombong mempunyai potensi untuk menjadi sumber air alternatif di Malaysia.

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| | | |
|---|---|---|
| AAS | - | Atomic Absorption Spectrometer |
| APHA | - | American Public Health Association |
| ASM | - | Academy of Sciences Malaysia |
| Cd | - | Cadmium |
| Cu | - | Copper |
| COD | - | Chemical Oxygen Demand |
| DO | - | Dissolved Oxygen |
| DOE | - | Department of Environment |
| EQA | - | Environmental Quality Act |
| Fe | - | Iron |
| KKM | - | Kementerian Kesihatan Malaysia |
| LUAS | - | Lembaga Urus Air Selangor |
| JMG | - | Jabatan Mineral dan Geosains |
| Mn | - | Manganese |
| MOH | - | Ministry of Health |
| MWA | - | Malaysian Water Association |
| NAHRIM | - | National Hydraulic Research Institute |
| NWQS | - | National Water Quality Standard |
| PACL | - | Poly Aluminium Chloride |
| PAX-10 | - | Poly Aluminium Chloride |

| | | |
|---|---|---|
| Pb | - | Lead |
| RWH | - | Rain water harvesting |
| SPAN | - | Suruhanjaya Perkhidmatan Air Negara |
| UMP | - | Universiti Malaysia Pahang |
| WQI | - | Water Quality Index |
| WHO | - | World Health Organization |
| Zn | - | Zinc |

# CHAPTER I

# INTRODUCTION

## 1.1 RESEARCH BACKGROUND

Rapid socioeconomic development is one of the factors that urge the water demand in Malaysia. Water bodies, especially rivers have been optimally utilized to meet the ever growing needs of these developments. The Malaysia Government is in a constant effort to identify and develop adequate water resources, preserve and to be in charge of all the available potential alternative water sources.

The primary raw water source abstracted to produce drinking water comes from the river. Due to the overwhelming pollution occurrence in rivers in Malaysia, it has become essential that the other water sources be developed and consumed to be served as an alternative water supply. Shah Alam and Sandakan had implemented the rainwater harvesting system in the new housing developments. Kelantan, Perlis, Pahang, Selangor, and Terengganu States have also been combining the usage of surface water and groundwater for their integrated resource management (Mohd Shawahid et al, Policies and Incentives for Rainwater Harvesting in Malaysia 2007 Rainwater Utilization Colloquium). It is vital to find another alternative to resolve the problems involving water scarcity in Malaysia, and using the ex-mining lakes as an alternative raw water source could be the answer.

The ex-mining pools have been used for various purposes including recreational activities, retention ponds, and irrigation. And recently in Selangor water from the ex-mining pools was pumped to the river to boost its flow. This somehow should be put into consideration for whether or not the water from disused mines is safe, considering that the water has been stagnant for quite sometimes.

## 1.2 PROBLEM STATEMENT

The increasing demands for clean water in Malaysia, combined with limited sources of clean raw water bodies to be abstracted to produce potable water, poses significant threats to the Nation's water sources. Though water scarcity in Malaysia is not a common phenomenon, the recent shortages occurring in Selangor and Kuala Lumpur area occurring was said to be due to the non-uniformity of rainfall and improper distribution and management of the water resources. However, the availability of good quality raw water is still reducing. This is reflected in the number of polluted and slightly polluted rivers are increasing.

Malaysia has a high dependency to rivers, as they are the primary raw water sources to be treated as drinking water, giving a proportion of 97% of drinking water sources in Malaysia came from the rivers. Pollution largely affects the stability and sustainability of raw water sources management in Malaysia. So it becomes mandatory that an alternative water source should be developed to reduce the water dependency to rivers.
Hence, this study was conducted to assess the water quality from the ex-mining lake in Bestari Jaya, resulting in the possibilities to use ex-mining lakes as an alternative water source. This could reduce the dependency to rivers to produce the clean raw water for drinking purposes and to provide an alternative to future water issues.

## 1.3 OBJECTIVES

This study serves 3 objectives as follows, based on the problem statement:

1) To study the water quality of ex mining lake in Bestari Jaya Selangor.

2) To examine the effectiveness of Alum and Poly Aluminium Chloride (PAX-10) as coagulants in lake water treatment.

3) To evaluate the potential of lake water as alternative water sources.

## 1.4 SCOPE OF STUDY

The scope of this study revolves around the water quality analysis of water samples of raw water from ex-mining lakes in Bestari Jaya, Selangor. These samples were compared and contrasted to set up a benchmark of a good water quality that complies with standard provided by the Ministry of Health Malaysia (MOH). The samples were brought to Environmental Laboratory, Faculty of Civil Engineering and Earth Resources, Universiti Malaysia Pahang (UMP) to be tested.

The water quality parameters of these water samples were identified in terms of physical, chemical and microbiological characteristics. A series of experiments were conducted to determine those characteristics. The study was sub-divided into two major methods of testing, the in-situ and ex-situ testing. The in-situ parameters were tested in the field, at each sampling points. Parameters involved include the temperature, pH, and Dissolved Oxygen (DO). The parameters considered for the ex-situ testing include Total Coliform and E. Coli, turbidity, Chemical Oxygen Demand (COD), the concentration of heavy metals, Cadmium (Cd), Zinc (Zn), Copper (Cu), Lead (Pb), Iron (Fe) and Manganese (Mn) using the AAS method. From these analyses, the potential of ex-mining lake in becoming alternative water source will be established.

## 1.5 SIGNIFICANT OF STUDY

This study was conducted to determine the potential of ex-mining lakes in becoming the alternative raw water source in Malaysia. This approach needs to be taken in consideration to find more alternative water sources in this country, to cope with the rising demand of water, giving solutions to water issues that occur quite more frequently these days. However, certain concerns regarding the idea of making water from ex-mining lakes, especially the public health concern should not be neglected. This study focuses on gathering as much proofs possible, regarding the suitability of water from mining lakes in terms of water quality to prove the potential of this water body to be considered as safe and reliable alternative water source. Ex-mining lakes will be added up to existing alternative water sources to cope with the future and present water scenarios and issues in Malaysia.

# CHAPTER II

# LITERATURE REVIEW

## 2.1 INTRODUCTION

This chapter consists of the literature review on the raw water sources in Malaysia, the water bodies, the ex-mining lakes, and related previous researches that had been done in accordance to the assessment risks of end use of ex-mining lakes and the potential that this water bodies have to serve Malaysia as future alternative water source.

## 2.2 WATER SCENARIO IN MALAYSIA

It is expected that the future demand in the year 2050 could be about 18 billion $m^3$. So it is understood that that the availability of raw water in Malaysia, generally, is not an issue. The water scarcity problem is probably due to the fact that rainfall is not uniformly scattered over the year temporally and spatially; base flow is reduced due to urbanization, demand is more than supply in the city centres, distribution network is not adequate for water distribution to high demand areas and water get polluted and rendered less suitable for the intakes when passing through the urban centres (Abdullah A. Mamun et al, 2013).

The recent water crisis in Selangor, Federal Territory Kuala Lumpur and Putrajaya was said to be one of the worst crisis ever occurred. Water rationing had to be imposed for more than two months duration. The shortage is not entirely due to inadequate capacity of Water Treatment Plants and distribution infrastructure, it is also due to inadequate resources charges. This issue arose due to the environmental issue, namely pollution and this is exacerbated by low flows of river water sources by industries and poorly operated sewerage treatment plants (Syed Muhammad Shahabudin, 2014).

### 2.2.1 Suruhanjaya Perkhidmatan Air Negara (SPAN)

Suruhanjaya Perkhidmatan Air Negara (SPAN) is the authority that is responsible to ensure long-term sustainability of quality of water and sewerage services through continued capital works development. They have come out with the statistics of several important water statistics in Malaysia.

#### 2.2.1.1 Malaysia Water Statistics

**Table 2.1:** Domestic Consumption in Malaysia (SPAN, 2013)

| State | Consumption Per Capita Per Day | |
|---|---|---|
| | l/cap/d | |
| | 2012 | 2013 |
| Johor | 221 | 223 |
| Kedah | 226 | 225 |
| Kelantan | 136 | 140 |
| Labuan | 164 | 167 |
| Melaka | 237 | 237 |
| N.Sembilan | 227 | 227 |
| Pulau Pinang | 294 | 296 |
| Pahang | 186 | 189 |
| Perak | 237 | 234 |
| Perlis | 241 | 242 |
| Sabah | 115 | 109 |
| Sarawak | 175 | 168 |
| Selangor | 235 | 235 |
| Terengganu | 205 | 211 |

### 2.2.1.2 Water Consumption in Malaysia

**Table 2.2:** Water Consumption in Malaysia (SPAN,2013)

| State | 2012 | | | | | 2013 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Domestic | | Non-Domestic | | TOTAL | Domestic | | Non-Domestic | | TOTAL |
| | MLD | % | MLD | % | MLD | MLD | % | MLD | % | MLD |
| Johor | 769 | 69.3 | 341 | 30.7 | 1,110 | 797 | 68.5 | 366 | 31.5 | 1,163 |
| Kedah | 474 | 74.2 | 165 | 25.8 | 639 | 487 | 74.8 | 164 | 25.2 | 651 |
| Kelantan | 130 | 69.2 | 58 | 30.8 | 188 | 140 | 69.5 | 62 | 30.5 | 202 |
| Labuan | 16 | 33.8 | 30 | 66.2 | 46 | 16 | 34.2 | 31 | 65.8 | 46 |
| Melaka | 187 | 51.7 | 175 | 48.3 | 362 | 193 | 51.4 | 182 | 48.6 | 375 |
| N.Sembilan | 247 | 56.3 | 192 | 43.7 | 439 | 255 | 54.5 | 213 | 45.5 | 468 |
| P.Pinang | 475 | 59.7 | 321 | 40.3 | 796 | 481 | 59.5 | 327 | 40.5 | 809 |
| Pahang | 287 | 57.8 | 209 | 42.2 | 496 | 299 | 59.3 | 205 | 40.7 | 504 |
| Perak | 592 | 73.1 | 217 | 26.9 | 809 | 607 | 72.6 | 228 | 27.4 | 835 |
| Perlis | 57 | 85.5 | 10 | 14.5 | 67 | 65 | 81.5 | 15 | 18.5 | 80 |
| Sabah | 305 | 57.6 | 225 | 42.4 | 529 | 314 | 59.2 | 216 | 40.8 | 530 |
| Sarawak | 432 | 56.3 | 336 | 43.7 | 768 | 446 | 56.4 | 345 | 43.6 | 790 |
| Selangor | 1,686 | 58.3 | 1,207 | 41.7 | 2,893 | 1,735 | 58.0 | 1,254 | 42.0 | 2,989 |
| Terengganu | 216 | 55.6 | 173 | 44.4 | 389 | 230 | 55.8 | 183 | 44.2 | 413 |
| MALAYSIA | 5,873 | 61.6 | 3,659 | 38.4 | 9,532 | 6,064 | 61.5 | 3,790 | 38.5 | 9,854 |

## 2.3 RAW WATER SOURCES

Raw water sources in Malaysia come from a various forms of water bodies. These water bodies provided a fresh raw water sources and have different proportion of abundances all over Malaysia. The sources include the rivers, rain, groundwater and lakes.

### 2.3.1 Rivers

A river is defined as any natural stream of water that flows in a channel with defined banks (Encyclopedia Britannica). Rivers may be initiated from a lake, a spring or an integration of small streams, known as headwaters. From these sources, the rivers flow downhill normally will be terminated into the ocean. Rivers initiated as small trickles of water up in the mountains. This is its source, and it eventually forms a small stream which then flows down the mountain. The water erodes the land, carving a bigger channel and forms the main river.

#### 2.3.1.1 River Basin

According to Department of Irrigation and Drainage Malaysia, River Basin can be defined as an area of land from which all surface run-off flows through a sequence of streams, rivers and lakes into the sea at a single river mouth, estuary or delta. There are 189 river basin systems with about 1800 rivers in Malaysia. The total length of the rivers is estimated to be 38,000 km. East Malaysia contains the country’s two longest rivers: the Rajang in Sarawak and the Kinabatangan in Sabah. They are each 560km long and navigable for part of their courses.

### 2.3.1.2 Roles of Rivers and River Basins in Malaysia

The primary role of rivers in Malaysia is to provide clean water supply to be utilized for the 25 million people currently living in Malaysia. Among the river basins, 30 0f them are reservoirs that supply 97% of raw water throughout the nation.

### 2.3.1.3 Abundance of River Basins in Malaysia

Stream or rivers are the primary raw water sources in Malaysia, contributing about 99% of raw water to be treated as drinking water. Table below shows all river basins that covers all area in Malaysia except islands other than Pulau Pinang and Pulau Langkawi.

**Table 2.3**: River Basins in Malaysia

| **Area** | **No. of Basin** | **Main Basin (> 80km$^2$)** | **Small Basin** |
|---|---|---|---|
| Peninsular Malaysia | 1,235 | 74 | 1,161 |
| Sabah | 1,468 | 75 | 1,393 |
| Sarawak | 283 | 40 | 243 |
| Total | 2,986 | 189 | 2,797 |
| Total Area | 327,897.031 | 312,863.713 | 15,033.858 |
| % Total Area | - | 95% | 5% |

The source of this information was gathered from The Register of River Basins in Malaysia (Phase II) by River Section of the Department of Irrigation and Drainage Malaysia.

### 2.3.1.4 State of River Water Quality

Despite the rivers' significance in supplying drinking water in Malaysia, most of the urban rivers today are severely polluted with all sorts of contaminants and pollutants including chemicals and rubbish due to improper and unsustainable development and management of rivers. It is found out that 50% of rivers in Malaysia remain clean, while the remaining proportions are polluted or considered dead rivers (NAHRIM), 2010).

### 2.3.1.5 Classes of Rivers (National Water Quality Standards)

Rivers in Malaysia are classified into several classes in accordance to the water quality obtained from laboratory testing. The most frequently referred local guidelines related to the water quality are the National Water Quality Standards (NWQS), Environmental Quality Act (EQA) and the Malaysian Water Association's (MWA) raw water quality criteria for the intakes. **Table 2.4** is an excerpt of the National Water Quality Standard (NWQS) whereas **Table 2.5** defines its respective beneficial uses (Department of Environment Malaysia, "Malaysia Environmental Quality Report 2006", In : Chapter 3 : River Water Quality).

**Table 2.4**: The Excerpt of National Water Quality Standards (NWQS)

| **Parameters** | **Unit** | **Classes** | | | | | |
|---|---|---|---|---|---|---|---|
| | | **I** | **IIA** | **IIB** | **III** | **IV** | **V** |
| Ammoniacal Nitrogen | mg/L | 0.1 | 0.3 | 0.3 | 0.9 | 2.7 | >2.7 |
| BOD5 | mg/L | 1 | 3 | 3 | 6 | 12 | >12 |
| COD | mg/L | 10 | 25 | 25 | 50 | 100 | >100 |
| DO | mg/L | 7 | 5-7 | 5-7 | 3-5 | < 3 | <1 |
| pH | | 6.5 - 8.5 | 6.5 - 9.0 | 6.5 - 9.0 | 5 - 9 | 5 - 9 | - |
| Color | TUC | 15 | 150 | 150 | - | - | - |
| Elec. Conductivity | µS/cm | 1000 | 1000 | - | - | 6000 | - |
| Total Suspended Solids | mg/L | 25 | 50 | 50 | 150 | 300 | 300 |
| Temperature | °C | - | Normal + 2 °C | - | Normal + 2 °C | - | - |
| Turbidity | NTU | 5 | 50 | 50 | - | - | - |
| Total Coliform | counts/ 100ml | 100 | 5000 | 5000 | 50000 | 50000 | >50000 |

**Table 2.5**: The Definition of Classes

| Class | Definition |
|---|---|
| I | Represent water bodies of excellent quality. Standards are set for the conservation of natural environment in its undisturbed state. |
| IIA | Represent water bodies of good quality. Most existing raw water supply sources come under this category. Class IIA standards are set for the protection of human health and sensitive aquatic species. |
| IIB | The determination of Class IIB standard is based on criteria for recreational use and protection of sensitive aquatic species. |
| III | Is defined with the primary objective of protecting common and moderately tolerant aquatic species of economic value. Water under this classification may be used for water supply with advanced treatment. |
| IV | Define water quality required for major agricultural irrigation activities which may not cover minor application to sensitive crops. |
| V | Represents other water that does not meet any of the above uses. |

#### 2.3.1.6 Water Quality Index (WQI)

The Water Quality Index (WQI) was formed in an attempt to simplify the substantial amount of data gathered coherent to the parameters listed in the NWQS, an indexing system was introduced (Zaki Zainudin, Benchmarking of River Water Quality Malaysia, 2010). A Water Quality Index (WQI) attributes the quality values to an aggregate set of measured parameters.

The aim of a WQI is to summarise large amounts of water quality data for a specific river into simpler terms. This makes the gradation system of water quality in Malaysia more understandable for the communities (K. Saffran et al, 2001).

**Table 2.6**: DOE Water Quality Index Classification

| **Parameters** | **Unit** | **Classes** | | | | |
|---|---|---|---|---|---|---|
| | | **I** | **II** | **III** | **IV** | **V** |
| Ammoniacal Nitrogen | mg/L | <0.1 | 0.1-0.3 | 0.3-0.9 | 0.9-2.7 | >2.7 |
| Biochemical Oxygen Demand (BOD5) | mg/L | <1 | 1-3 | 3-6 | 6-12 | >12 |
| Chemical Oxygen Demand (COD) | mg/L | <10 | 10-25 | 25-50 | 50-100 | >100 |
| Dissolved Oxygen | mg/L | >7 | 5-7 | 3-5 | 1-3 | <1 |
| Ph | mg/L | >7 | 6-7 | 5-6 | <5 | >5 |
| Total Suspended Solids (TSS) | mg/L | <25 | 25-50 | 50-150 | 150-300 | >300 |
| Water Quality Index | mg/L | >92.7 | 76.5-92.7 | 51.9-76.5 | 31.0-51.9 | <31.0 |

### 2.3.2 Rain

Rainwater is a part of hydrologic cycle: the never-ending exchange of water from the atmosphere to the water bodies back again as rainwater. The precipitation like hail, rain sleet and snow and all the consequently movement of water in nature forms a part of this cycle ( Che Ani A.I et al, 2009).

#### 2.3.2.1 Abundance of Rain in Malaysia

Located near equator, Malaysia is categorized as an equatorial climate country, being hot and humid throughout the year. Annually, Peninsular Malaysia receives 324 billion $m^3$ of rainwater on average; where the current demand is about 11 billion $m^3$ only (Economic Planning Unit – EPU. “National Water Resources Study 2000- 2050”).

#### 2.3.2.2 Rainwater Harvesting

Rainwater harvesting is a traditional practice that dates back hundreds of years. Archeological evidence certify to the apprehension of rainwater as far as 4,000 years ago and the idea of rainwater harvesting in China may date back 6,000 years ago ( Texas Water Development Board, 2005).

This system has been implemented widely by numerous developed countries. USA, Japan, China, Germany, and Australia have been using this system to support the increasing water demand. The integration between rainwater harvesting system and existing conventional water supply system will help to serve the water demand and it will be conducive in promoting the sustainability of the water supply.

#### 2.3.2.3 Rainwater Harvesting in Malaysia

Rainwater harvesting lately has gained recognition as a sustainable means of domestic water supply globally. Malaysia as a country that received a very high rainfall throughout the year is not fully capitalized on this (Ar Zuhairuse Md Darus, Potential Development of Rainwater Harvesting in Malaysia).

After 1998 drought, a study of alternative source of water supply is being carried out. In 1999, a guideline for installing a rain water harvesting policy in Malaysia was introduced. It aims is to reduce dependence on treated water.

In this country, the implementation of this system has been successfully implemented in certain locations involved. Case studies by NAHRIM indicated that this system has shown a positive outcome in terrace houses communities in Sandakan, Sabah, Damansara Selangor, One Utama Shopping Complex, and Taman Bukit Indah Mosque.

#### 2.3.2.4 Rainwater Harvesting Policy in Malaysia

The Ministry of Energy, Water and Communication (MEWC) has been appointed as the implement agency that also involved in Rain Water Harvesting (RWH). In addition, in March 27, 2006, Government announced that is mandatory to implement RWH to large building like factories, school or institution and bungalow.

### 2.3.3 Groundwater

#### 2.3.3.1 Abundance of Groundwater in Malaysia

Research from Jabatan Mineral dan Geosains Malaysia (JMG) confirmed that up until now, only 3% of water supply in Malaysia used up the groundwater. The usage of groundwater in Kelantan has exceeded more than 70%, and groundwater is served as public water supply.

The groundwater in Malaysia is not well developed due to certain reasons; 1) the failure to recognize the potential of groundwater, 2) misconception of groundwater 3) lack of full assessment of the resource, and 4) lack of strategic and action plans.

**2.3.3.2 State of Groundwater Development in Malaysia**

In Peninsular Malaysia, the development of groundwater started since the early 1900 in Kelantan. Up until now, about 0.2 million $m^3$/day of groundwater has been exploited in that state. In Sarawak, the first recorded abstraction by tube wells was in 1954 in Sarikei, followed by similar schemes in Bintangor and Sri Aman. Groundwater is considered as main source of water supply in several coastal villagessuch as Belawai, Igan, Oya, Kabong, Pulau Bruit, Tatau, Limbang and several other new schemes under development, and until now about 0.05 million $m^3$/day of groundwater is being exploited in Sarawak. (Mohammed Hatta Abd Karim,JMG).

**2.3.3.3 Misconception of Groundwater Resource in Malaysia**

There were several misconceptions occurring regarding the groundwater resource in Malaysia and due to these misconceptions, groundwater management is not well developed. People tend to think that groundwater is a very limited source in Malaysia, so it has to be preserved well. Without a proper technology and expertise, groundwater is considered difficult to be extracted. JMG has developed a technology for groundwater development. The newer technology such as the artificial aquifer or the temporary catchment, collector drain and gallery should be considered. The misconception that groundwater is highly polluted can be explained by the fact that the aspects of preventing the groundwater pollution is the identification of recharge area for the aquifer. In such, the protection of the recharge is vital.

### 2.3.4 Lakes

A lake is defined as a substantial body of water, and it can be natural or man-made. A pond on the other hand, is normally referred to as a small body of water usually man-made.

#### 2.3.4.1 Abundance of Lakes in Malaysia

According to National Hydraulic Research Institute (NAHRIM), a preliminary assessment listing suggests that there are over 90 lakes in the country covering an area of at least 100,000ha and hold about 31 billion cubic meters of water. **Table 2.7** shows the number and locations of existing lakes in Malaysia.

**Table 2.7**: The Inventory of Lakes in Malaysia

| **No.** | **State** | **Number** | **Area ($km^2$)** | **Volume ($M\ m^3$)** |
|---|---|---|---|---|
| 1. | Perlis | 2 | 13.33 | 40.00 |
| 2. | Kedah | 7 | 105.625 | 2486.36 |
| 3. | Perak | 11 | 284.68 | 6766.50 |
| 4. | Selangor | 15 | 11.38 | 511.32 |
| 5. | Pahang | 10 | 94.69 | 321.51 |
| 6. | Kelantan | 4 | 17.41 | 88.94 |
| 7. | Johor | 13 | 84.47 | 940.024 |
| 8. | Labuan | 3 | n.a | 5.4 |
| 9. | Melaka | 4 | 8.75 | 81.3 |
| 10. | N.Sembilan | 5 | 2.25 | 182.325 |
| 11. | P.Pinang | 4 | 0.936 | 47.2 |
| 12. | Sabah | 5 | n.a | 29.61 |
| 13. | Sarawak | 4 | n.a | 6080 |
| 14. | Terengganu | 2 | 370.8 | 13600 |
| 15. | Putrajaya | 1 | 7.5 | 45 |
| | Total | 90 | 1,001.821 | 31,225.489 |

#### 2.3.4.2 State of Lake Water Quality

In October 2004, the Academy of Sciences Malaysia (ASM) and the National Hydraulic Research Institute of Malaysia (NAHRIM) had initiated a study to provide a baseline appraisal of the current state of the country's lakes and reservoirs. This study has been undertaken by the Institute of Environment and Water Resource Management, Universiti Teknologi Malaysia, the resulting report entitled A Study on the Status of Eutrophication of Lakes in Malaysia, confirmed that the condition of Malaysian lakes largely reflected the global situation. The study focused on the status of Eutrophication for 90 Major lakes & reservoirs in Malaysia, showed that 56 lakes which is (62%) of them were in a poor condition (eutrophic), while the remaining 34 lakes (38%) were in mediocre to reasonable good state (mesotrophic). These results proved that the eutrophication of lakes in Malaysia has reached levels for a very serious concern and restoration efforts were urgently needed (Syazrin Syima Sharifuddin, National Hydraulic Research Institute of Malaysia).

## 2.4 EX-MINING LAKES

Ex-mining lakes are the outcome of mining operations that has been carried out years before, in a specific area. This operations left behind an open pit lakes, ponds, tin tailings (sand and slime tailings) and areas of mixed materials. It is estimated that there are about 210,000 hectares of ex-mining land in Malaysia, and most of these areas has been rehabilitated into useful lands (IR Khong Peng Seong, "Ex-tin Mining land in Malaysia: a valuable asset and resource," in 2000 conference on Asia-Pacific Mining and Quarrying (APMQ), 2000). There is 4909.6 hectares of ex-mining land in Selangor and the area under study is still in need of rehabilitation works (Jabatan Mineral dan Geosains (JMG), 2008). There are a lot of environmental hazards that were associated to these ex-mining areas. These may include threats to natural reserves due to landscape changes, damage to natural drainage, pollution and destruction of natural habitats (TED database, case studies, and tin mining in Malaysia).

### 2.4.1 Malaysian Mining Laws and Codes

The environmental issues caused by tin mining have been reduced with the help of governments in Legislations of Malaysia. The legislations involved were The Mining Codes of Perak (1895) and Negeri Sembilan (1895), The Mining Enactment No. 7 (1899), The Selangor Mining Enactment (1901), (1911), (1921), (1928) etc. (G. Balamurugan, "Tin mining and sediment supply in Peninsular Malaysia with special reference to the Kelang Riverbasin," The Environmentalist Vol.11, no. 4, pp.281-291, 1991). Most of these laws were focusing on mining code of practice but it was not primarily discuss on environmental issues, so The F.M.S Mining Enactment (1934) was the first to introduce the environmental standards.

### 2.4.2 Alternative End Uses of Ex-mining Lakes

In recent years, mining companies, mining communities and regulatory agencies have begun considering the potential beneficial end uses for mine lakes. The beneficial end uses of these lakes are unlikely to be without environmental impacts (Robert G. et al, Environmental Risks Associated with Beneficial End Uses of Mine Lakes in Southwestern Australia, 2005). The following are the alternative end uses that have been either proposed or implemented for mine lakes:

- Recreation and tourism; a mine lake may be developed as a facility for swimming, boating, recreational fishing, or diving (Acott 1989: Brenner et al. 18987; Chapman 2002; Edwards et al. 1996; Klapper and Geller 2001; Pretes 2002).
- Wildlife conservation; the mine lake may be maintained as a permanent wetland habitat in areas where natural wetland habitat in areas where natural wetlands have been lost due to agricultural or urban development (Bell 2001; Greenway and Simpson 1996).

- Industrial water source; extractes mine lake water can be used in a range of industrial processes for cooling, boiler feed, wash down, dust suppression, and fire fighting (Anderson 1996; Tcobanoglous and Angelakis 1996)
- Livestock water source; water may be extracted to provide drinking water for livestock production, especially in arid rangeland (Harper et al. 1997).

From these studies, it is found that mine lakes do have a huge potential of beneficial end use for human but it is still questionable that water from these lakes is suitable as portable water source.

### 2.4.3 Ex-Mining Lakes as an Alternative Water Source

River is the main raw water supply in Malaysia and because of that it is questionable, whether or not the water supply will be sustainable in years ahead. The idea of using ex-mining lake as an alternative water sources was pioneered by Lembaga Urus Air Selangor (LUAS). In this study, mine lakes are chosen as a potential alternative water sources as these lakes are quite abundant in terms of existence in regions around Peninsular Malaysia.

According to LUAS, the implementation of these alternative ponds in Bestari Jaya, had helped a lot in increasing the source of raw water supply in Selangor besides controlling the flow of flooding water from Sungai Selangor (Md. Khairi,LUAS). By referring to the analyzed results of water sampling done by Kementerian Kesihatan Malaysia (KKM) to the lakes recognized, within a timeframe of 2011 to 2013, results show that the quality of water from these lakes comply with the Recommended Raw Water Quality and National Standard for Drinking Water Quality. Results dated 2$^{nd}$ February 2014, Mercury, Cadmium, Arsenic, Lead, Copper, Sodium and Magnesium in the water samples were found to be within the prescribed limit.

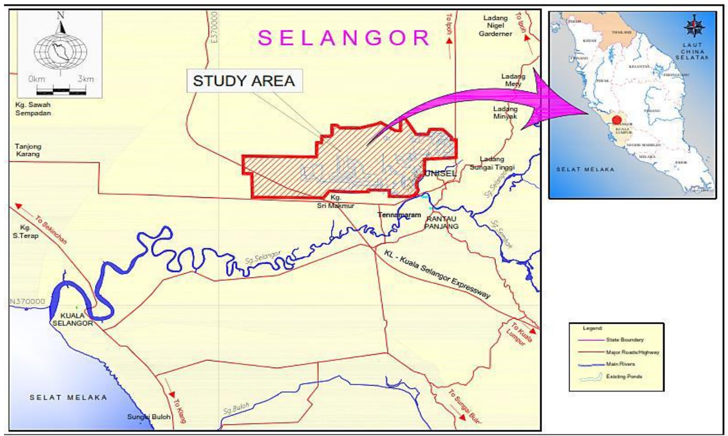


**Figure 2.1:** The Study Area of Alternative Water Source Lakes

### 2.4.3.1 Criteria of Ponds, Lakes and Ex-mining Lakes Alternative Water Source

Lembaga Urus Air Selangor (LUAS) is the authority that involves in the implementation of using water from lakes and ex-mining lakes as alternative water sources. In order for these lakes to meet the standard and public health concern, a certain criteria and parameters had been set up. **Table 2.8** summarizes the criteria of lakes and ex-mining lakes to be selected as alternative water sources.

**Table 2.8:** The Criteria of Lakes and Ex-Mining Lakes (LUAS, 2014)

| **Lake Characteristics** | **Criteria** |
|---|---|
| Lake Size | The size of lakes or ex-mining lakes must be at least 10 acres. |
| Location | The lakes or ex-mining lakes must be near to rivers. |
| Access | Must have an easy access to ease the works ahead. |
| Distance to Raw Water Intake Station | The lakes or ex-mining lakes must be near to the Raw Water Intake Station for cost efficiency. |
| Water Quality | The water quality should comply the standards prepared by WHO and the results must be recognized by Kementerian Kesihatan Malaysia (KKM). |

### 2.4.3.2 The Development of Alternative Water Source Ponds (HORAS 3000) in Selangor

The research on Ex-Mining Lakes as a flood detention area in Bestari Jaya has increased the sustainability of water resource in Selangor. Research done by Jurutera Perunding Zaaba Sdn Bhd dated 31st December 2013 proved that based on a test conducted on eight (8) sampling points at the ex-mining lakes in Bestari Jaya, it was found that four (4) samples of water from these sampling points falls under Class II of WQI, one (1) in the Class III and the three (3) remaining falls under Class IV of the WQI. This research proved that water from these sources has a potential in becoming a safe alternative water source.

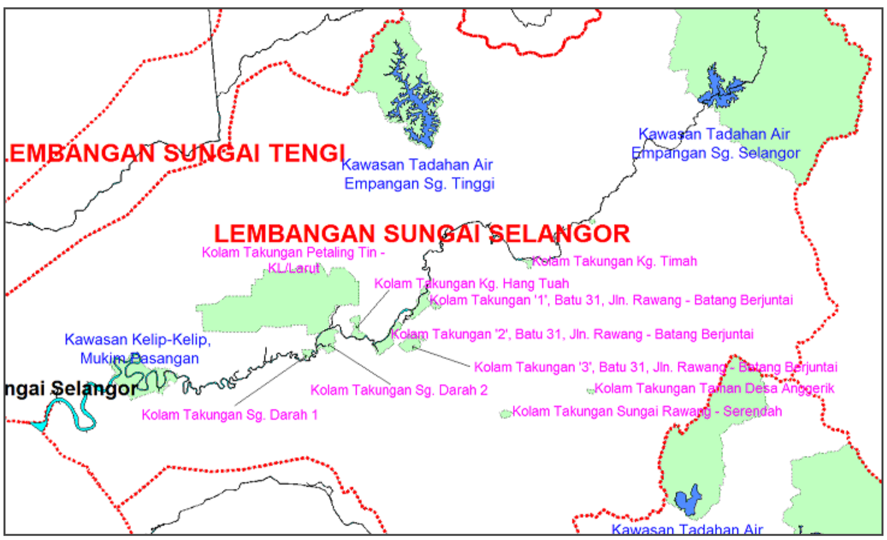


**Figure 2.2:** Locations of Alternative Water Source Lakes in Selangor

### 2.4.4 Heavy Metals Constituents in Water from Ex-Mining Lakes

Heavy metals contained in residues coming from mining and metallurgical operations are often dispersed by wind and water after their disposal. In addition, the pollution of soil and groundwater by dissolved heavy metals has mainly been associated with Acid Mine Drainage (AMD), one of the most serious environmental hazards of mining industry. Previous studies such as those of Asklund (2005), Wang and Mulligan (2005), Navarro et al. (2007) suggested that mining is one of the most important sources of heavy metal contamination in the environment.

For the abandoned mine, the resultant waste consists of roaster piles, tailings ponds, waste rock piles and acid mine drainage. Percolation from the tailing ponds has contaminated ground water below and down gradient of the ponds. The ground water discharges to a nearby stream and so do the runoff from the roaster, waste piles and acid mine drainage. In particular, the main concentrations of concern are arsenic, iron, copper, lead, manganese, nickel, and zinc that exceed water quality criteria in the stream (Fares Yahya et al. (2009) ).

As stated by previous studies by Fares et al. (2009), heavy metals occur naturally as a result of mineral deposition processes. For instance, arsenic is usually an unusable byproduct that may introduce into the environment through the natural process of erosion of mineral deposits or through mining and milling of these deposits. Metals or mineral decomposition products may be present in mine water, mine dump rock, mill tailings or nearby soils, or water bodies.

## 2.5 Heavy Metal Removal from Raw Water

Heavy metal removal is a crucial step in water-treatment processes. The main objective of water treatment is to achieve the required standard of final water quality regardless of the quality of the source water. It was observed that the extents of water treatment mode for domestic purposes are highly dependent to the raw water source quality. Certain sources like rivers require more extensive treatment than others (Rossi and Ward, 1993).

### 2.5.1 Coagulation

In drinking water treatment, the coagulation process is used to destabilize colloidal material and convert dissolved organic material to a solid phase for subsequent removal by solid-liquid separation processes such as sedimentation, dissolved air flotation, and filtration. Important raw water quality parameters for coagulation include turbidity, total organic carbon (TOC), color, hardness and alkalinity (David J. P., 2001).

### 2.5.2 Coagulants

Coagulant can be defined “an agent that induces curdling or congealing. In water treatment sense, coagulant refers to a type of chemical that will remove colour and turbidity present in raw water in the form of flocs (Peter G., 2005).

Various types of coagulants are widely used in conventional water-treatment processes in order to produce potable water. Coagulants can be classified into inorganic coagulants, synthetic organic polymer and naturally occurring coagulants. They are used for various purposes depending on their chemical characteristics. An inorganic polymer ‘PAC’ (poly aluminium chloride) is the most widely used coagulant in water treatment (Van Benchosten and Edzwald, 1990; Boisvert et al., 1997; Najm et al., 1998; Okuda, et al., 1999, 2001).

The selection of the appropriate coagulant for a given water treatment application was found to depend on the chemical characteristics o f the coagulant, the characteristics of the raw water, and the treatment process used (David J. P., 2001).

**2.5.2.1 Alum**

Alum has traditionally been used as coagulants in the drinking water industry. This metal undergoes rapid, uncontrolled hydrolysis reactions upon its addition to water forming soluble ionic species and a solid precipitate. The charge of the dominant ionic species in solution is pH dependent. At low coagulant doses and favorable pH, positively charged species can neutralize the negative charge on colloidal contaminants and lead to destabilization. At higher coagulant doses, large amounts of precipitated aluminum or ferric hydroxides are formed, which provide a large surface area for the adsorption and enmeshment o f contaminants (David J. P., 2001).

Aluminum Sulphate or Alum is the typical coagulant type that has been used by most water treatment plants all over the world because of its lower cost and widespread availability. The use of Alum in treating water often requires the use of coagulant aid such as lime and soda ash to ensure that the optimum coagulation pH is achieved. The chemistry of alum has been studied extensively, its coagulation mechanisms are well understood, and guidelines for their use as drinking water coagulants are well established.

Though Aluminium-based coagulants are frequently used in water treatment there are fears that Aluminium may induce Alzheimer’s disease (Crapper et al., 1973; Miller et al., 1984; Martyn, et al., 1989). They might as well exhibit strong carcinogenic properties (Mallevialle et al., 1984). Some domestic tap waters may contain Aluminium in relatively high concentrations because Aluminium has been added as a flocculant during the purification process (DWAF, 1996). The implication of this may be very serious and critical since Aluminium ions have been demonstrated to be toxic especially in individuals with impaired renal function (Savory and Wills, 1991).

### 2.5.2.2 Poly Aluminium Chloride

In recent years, Poly Aluminum coagulants have received considerable interest as drinking water coagulants. Various types of Poly Aluminum coagulants are commercially available for water and wastewater treatment, including Poly Aluminum Chloride (PACI), Aluminum Chlorohydrate, Poly Aluminum Sulfate (PAS), and Poly Aluminum Silica Sulfate (PASS). Unlike Alum, these products differ in their basicity and strength, and can contain varying amounts of other substances, such as sulfate, silica, and calcium. Poly Aluminum coagulants are produced by the slow addition of base to aluminum salts (David J. P., 2001).

Poly Aluminium Chloride or PACL is a type of coagulant consisting of Al2(OH)3Cl3. The specific type of PACL that has been used in this study is called PAX-10 due to its low basicity. PAX-10 is used alternatively instead of Alum and is suitable for raw water that has low pH and alkalinity.

## 2.6 Previous Studies on Ex-Mining Lakes

As a guideline, previous studies had been used as close reference especially on the potential of ex-mining lakes in performing various end-use and the risk that it might hold substantially. **Table 2.9** shows the summary of analyses done on water from various ex-mining lakes.

**Table 2.9:** Potential environmental risks from different beneficial end uses of mine lakes and mine lake water in basin (Robert G. Doupé and Alan J. Lymbery, 2005).

| End Use | Overall Risk Score | Major Environmental Impacts |
|---|---|---|
| Wildlife Conservation | 7 | Additional wetlands may affect public health through an increased prevalence of vector borne diseases, by providing vector breeding sites or increased numbers of reservoir hosts (Norris 2004; Patz et al. 2000; Russell et al. 1997). |
| Chemical extraction | 9 | Processes involved in chemical extraction may produce emissions leading to land, water, or atmospheric pollution (Ericsson and Hallmans 1994). |
| Industrial water source | 9 | Some industrial uses, for example cooling and dust suppression, have the potential for human health risks through the aerosol transmission of pathogens (Anderson 1996; Geldreich 1996; Tchobanoglous and Angelakis 1996). |
| Potable water source | 10 | The transmission of pathogens or chemicals such as heavy metals through drinking water is a public health concern, often leading to public aversion to potable reuse, even when treatment systems are installed (Anderson 1996; Geldreich 1996; Tchobanoglous and Angelakis 1996). |

**Table 2.9:** Continued

| End Use | Overall Risk Score | Major Environmental Impacts |
|---|---|---|
| Livestock water source | 11 | The consumption of mine water by livestock may have public health implications due to accumulation of heavy metals or other chemicals in edible tissues (Harper et al. 1997). In addition, there may be increases in soil erosion and impacts on biodiversity of terrestrial ecosystems if greater water availability leads to an expansion of agricultural land. |
| Aquaculture | 11 | Aquaculture has the potential to pollute water by nutrient enrichment (Axler et al. 1996a, b; Viadero and Tierney 2003). Aquaculture also poses a potential threat to aquatic biodiversity if exotic species are farmed and can escape into natural waterways (Starcevich et al. 2003). |
| Recreation and tourism | 13 | Recreational use of a mine lake increases the potential for land, water, and atmospheric pollution due to increased human traffic (Chapman 2002). Health and safety issues arise through human contact with water pathogens or untreated chemical contaminants (Geldreich 1996; Tchobanoglous and Angelakis 1996), and through water sports, especially those involving powerboats (Chapman 2002). |
| Irrigation | 15 | Any irrigation has the potential for waterlogging and secondary salinisation due to increased groundwater recharge, affecting biodiversity in terrestrial and aquatic ecosystems (Annandale et al. 2001; Johnson and Wright 2003). An additional issue with the use of mine lake water is the possibility of heavy metal deposition and accumulation in soil and crop plants, leading to pollution and public health concerns (Al Jamal et al. 2002) |

**Table 2.10:** Previous Studies on Ex-Mining Lakes

| References | Study Area | Findings | Remarks |
|---|---|---|---|
| K U Orji, N Sapari, K W Yusof, R Asadpour, and E Olisa, 2013. | Ex-mining lakes around Tronoh, Batu Gajah and Sungai Kinta. | Analyses proved that the rivers and the mining lakes are highly turbid, have high concentrations of Pb, and have common water quality problem. | The result implies that water from the ex-mining lakes can also be utilized for water supply after treatments. |
| Muhammad Aqeel Ashraf, Mohd. Jamil Maah and Ismail Bin Yusoff, 2010. | Old tin mining area in Bestari Jaya, Sungai Ayer Hitam, Sungai Selangor. | The results of water quality trends clearly show that majority of water quality parameters are quite high and fall in Class III in terms of Malaysian Interim Water Quality Standards. | A lot of research needs to be carried out to access the pollution impact of the area on the environment and for the rehabilitation and reclamation steps to be taken. |
| Fares Yahya Alshebi, Wan Zuhairi Wan Yaacob, Abdul Rahim Samsudin, and Esmail Alsabahi, 2009. | Risk Assessment at Abandoned Tin Mine in Sungai Lembing, Pahang, Malaysia. | It is found that all heavy metals measured, As, Pb, Cu, Zn, and Ni present in high concentrations. According to the data, the abandoned tin mine of Sungai Lembing is contaminated with Pb> Cu> Ni> Zn > As> Cr. | The results suggest that there is a vital increase of heavy metal risk in this area. Polluted heavy metals dispersion is mainly associated, at this site, with water transportation of mine waste through the flowing streams. |

**Table 2.10:** Continued

| References | Study Area | Findings | Remarks |
|---|---|---|---|
| Robert G. Doupé and Alan J. Lymbery, 2005 | Ex-coal mining lakes, Collie Basin,Western Australia. | Ex-mining lakes hold a huge potential in various end uses, focusing on recreation and tourism, aquaculture and horticulture, but these end-use may still have substantial environmental risks. | There is currently no regulatory guideline in Western Australia that addresses closure criteria or the long term performance of mine lakes. These guidelines should be implemented to make it easier for mining communities to evaluate economic, social and environmental costs and benefits of different end use options for mining lakes. |

# CHAPTER III

# RESEARCH METHODOLOGY

## 3.1 INTRODUCTION

The main aim of this chapter is to verify the methods to conduct this research, in order to identify the results of analysis of water quality from within the sampling points. This chapter provides a step-to-step processes and tasks that need to be completed in order to achieve the outcome and objectives of this research.

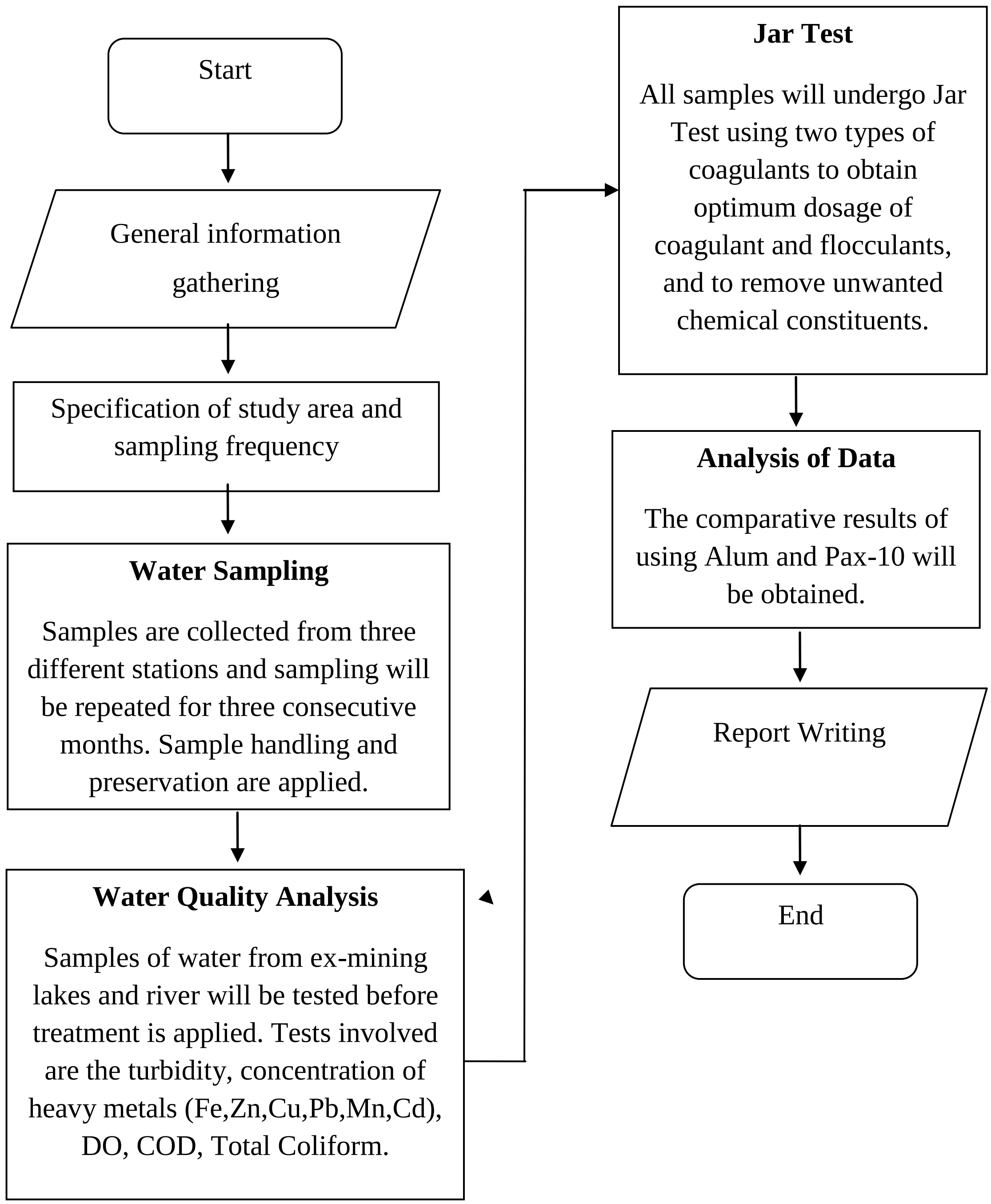


**Figure 3.1**: Flow chart of the experiments

## 3.2 SAMPLING

In conducting experiments, the sampling process comprises of the study area, the location of sampling points, sampling frequency, sampling methods, and storage of samples. These processes are important to preserve the samples' conditions and data validity.

### 3.2.1 Study Area

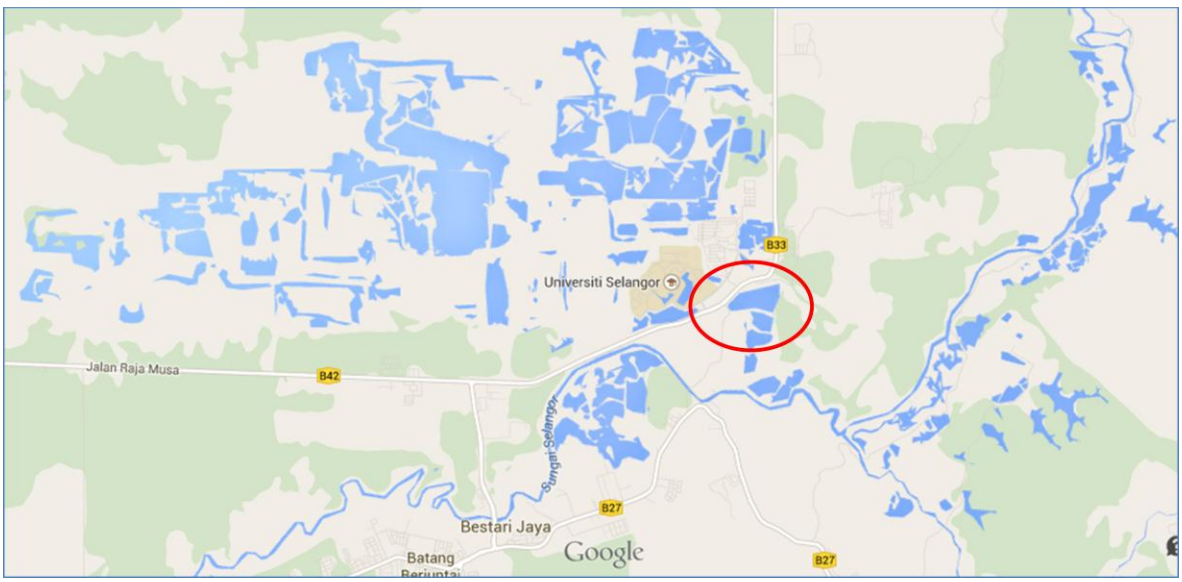


**Figure 3.2:** Location of the study area

The study area, Bestari Jaya or formerly known as Batang Berjuntai is located at 30' 24' 40.41" N and 101' 24' 56.23" E is a part of Kuala Selangor district in Selangor state. The average temperature of this specific area is 32 C during day and 23C at night. An annual average rainfall of 2000 mm and 3000 mm with potential evaporation of 1600 mm throughout the year ( Department of Irrigation and Drainage, Hydrology and Water Resource Division). Bestari Jaya had the history of becoming an old tin mining area for over ten years. The whole catchment covers an area of 2.656.31ha. The catchment flows downstream to Sungai Ayer Hitam and Sungai Udang which finally end up with Sungai Selangor (Muhammad et al, 2010).

This location was chosen as the area of study due to the fact that it has been implementing the lakes as alternative water sources. Water from the ex-mining lakes in Bestari Jaya had been channeled to the main raw water intake station, Sungai Selangor to boost up the flow of this river. The real implementation of this issue has made it easier for this study to be completed.


**Figure 3.3:** Locations of sampling points

### 3.2.2 Sampling Methods (Handling and Preservations)

The samples was prepared at the sampling area which located about 3 hours journey to the testing laboratory in Universiti Malaysia Pahang, so it was mandatory that all samples were well prepared and preserved in the right ways so that the data is valid throughout the research duration. **Table 3.2.2** summarizes the recommended holding time and preservation methods that had been applied to the samples.

**Table 3.1:** Recommended holding times and preservation methods

| **Parameter** | **Container** | **Preservation** | **Holding Time** | **Reference** |
|---|---|---|---|---|
| Alkalinity | Plastic/Glass | Cool to 4°C | 14 days | APHA |
| Colour | Plastic/Glass | Cool to 4°C | 2 days | APHA |
| Hardness | Plastic/Glass | Fill bottle, Cool to 4°C | 7 days | AS/NZS 5667.1:1998 |
| pH | Plastic/Glass | None required | 6 hours | AS/NZS 5667.1:1999 |
| Solids | Plastic/Glass | Cool to 4°C | 7 days | APHA |
| Turbidity | Plastic/Glass | Store in dark, Cool to 4°C | 2 days | APHA |
| Metals General | Plastic/Glass (Acid Washed) | Add HNO3 to pH< 2 | 6 months | APHA |
| BOD | Plastic/Glass | Cool to 4°C | 2 days | APHA |
| COD | Plastic/Glass | Add H2SO4 to pH< 2, Cool to 4°C | 28 days | APHA |
| Microbiological Tests | Plastic/Glass (Sterile) | Add 0.008% Na2S2O3, Cool to 4°C | 1 day | USEPA SW846 Jan 1998 |

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## 3.3 MATERIAL AND EQUIPMENTS

The laboratory testing of this study consists of three (3) main properties of parameter, namely the physical properties, chemical properties and microbiological properties. These properties need a specific reagents and equipments in order for the tests to be conducted. For analytical purposes, the equipments used comprised of the pH meter, Turbidimeter, BOD machine reactor, COD machine reactor, the Atomic Absorption Spectrometer (AAS) for measuring the heavy metals concentration. The heavy metals involved in this water quality test were Lead (Pb), Copper (Cu), Manganese (Mn), Iron (Fe), and Zinc (Zn). The reagents involved in analyzing the water quality are listed in **Table 3.3**.

**Table 3.2:** The parameter and reagent used in water quality analysis

| Parameter | Material/Reagent |
|---|---|
| BOD | Phosphate buffer (pH 7.2), Magnesium Sulphate, Calcium Chloride, Ferric Chloride |
| COD | COD High Range Reagent Solution |
| Total Coliform | Snap Packs for 100ml sample |
| Ammonia as NH3-N | Ammonia High Range Reagent Solution |
| Lead | Lead Reagent Solution |
| Copper | Copper Reagent Solution |
| Manganese | Manganese Reagent Solution |
| Iron | Iron Reagent Solution |
| Zinc | Zinc Reagent Solution |
| Chromium | Chromium Reagent Solution |

## 3.4 WATER QUALITY ANALYSIS

The laboratory analysis of water from the ex-mining lakes and Sungai Selangor will be conducted in three main water quality characteristics. The characteristics are the physical, chemical, and biological parameters.

### 3.4.1 Physical Parameters

Physical parameters are the characteristics of water that respond to the senses of sight, touch, taste, or smell. Turbidity, colour, and temperature fall into this category.

#### 3.4.1.1 Temperature and pH

Temperature and pH of water play a major role in assessing water quality. They affect physical properties of water. The water temperature and pH was tested in-situ, using pH meter.

#### 3.4.1.2 Turbidity

Turbidity is a measure of the extent to which light is either absorbed or scattered by suspended material in water. The level of turbidity will be measured in NTU using Turbidimeter.

### 3.4.2 Microbiological Parameters

#### 3.4.2.1 Total Coliform and E.Coli

Total Coliform was tested using Most Probable Number (MPN) method. The procedures of this method will be following the Standard Methods for the Examination of Water and Wastewater 21st Edition (American Public, Health Association, New York 2002).

**Figure 3.4:** Most Probable Number (MPN) method

### 3.4.3 Chemical Parameters

#### 3.4.3.1 Chemical Oxygen Demand (COD)

The test was conducted in reference to the Standard Methods APHA 5220-C. It was done to determine the chemical oxygen demand of the raw water samples. Samples were then heated at 150°C in the COD reactor for 2 hours. After the sample had cooled down for 40 minutes, or the temperature had reduced to room temperature, the reading was taken. The concentrations of COD were measured using Spectrophometer HACH DR 5000 model.

### 3.4.3.2 Heavy Metals

Heavy metal concentrations for this study were determined using Atomic Absorption Spectrometer (AAS). Heavy metals involved in this water quality test were Iron, Zinc, Manganese, Copper, Lead, and Cadmium.

## 3.5 Lake Water Treatment

Water samples from the ex-mining lake will be treated using lab scale treatment method of coagulation using Jar Test. The water samples will be treated using two different types of coagulants namely Alum and Poly Aluminium Chloride (PAX-10). This will result in the comparison of the effectiveness of the two coagulants. The most efficient coagulant to treat water from the ex-mining lakes will be observed.

**Figure 3.5:** Jar Test

# CHAPTER IV

# RESULTS AND ANALYSIS

## 4.1 INTRODUCTION

This chapter will discuss in detail the results obtained from series of experiments done on the raw water samples from the ex mining lake in Bestari Jaya, Selangor. All data will then be presented in graphical approach for evaluation analysis processes. The experiments were conducted in three consecutive months for data variation and comparison purposes.

## 4.2 CHARACTERISTICS OF RAW WATER FROM EX-MINING LAKE

**Table 4.1** sums up the raw water quality obtained in three stations. The sampling was done in three consecutive months to obtain more data to increase the precision of data. The raw water samples were initially analyzed for Turbidity, Chemical Oxygen Demand (COD), Total Coliform and E.Coli, and heavy metal constituents. The heavy metals involved are Iron (Fe), Manganese (Mn), Copper (Cu), Lead (Pb), Cadmium (Cd) and Zinc (Zn).

**Table 4.1**: Comparisons between the raw water quality analysis from the ex-mining lake and the prescribed limits based on the Drinking Water Quality Standard (Raw Water), Ministry of Health, Malaysia.

| Test Parameters | Unit | March | | | April | | | May | | | MOH Standard |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Station 1 | Station 2 | Station 3 | Station 1 | Station 2 | Station 3 | Station 1 | Station 2 | Station 3 | |
| Temperature | °C | 32.4 | 33 | 33.2 | 34.7 | 34.4 | 34.3 | 34.7 | 34.4 | 34.3 | - |
| pH | - | 5.83 | 5.31 | 4.65 | 6.83 | 5.21 | 4.55 | 6.83 | 5.21 | 4.55 | 5.5-9.0 |
| Turbidity | NTU | 2.3 | 3.33 | 1.14 | 2.47 | 3.86 | 2.12 | 2.78 | 3.33 | 3.07 | 1000 |
| Total Coliform | MPN/100ml | 755.6 | 73.3 | 42.5 | 235.6 | 53 | 43 | 143 | 65.6 | 67.3 | 5000 |
| E. Coli Count | MPN/100ml | 1 | ND | ND | ND | ND | 1 | ND | ND | 1 | 5000 |
| D.O | mg/l | 10.59 | 10.3 | 10.68 | 10.89 | 10.42 | 10.82 | 10.89 | 10.42 | 10.82 | 5 |
| COD | mg/l | 30 | 59 | 64 | 65 | 66 | 46 | 66 | 65 | 40 | 10 |
| Iron | mg/l | 0.021 | 0.041 | 0.049 | 0.021 | 0.004 | 0.027 | 0.032 | 0.002 | 0.03 | 1 |
| Manganese | mg/l | 0.242 | 0.251 | 0.242 | 0.24 | 0.255 | 0.255 | 0.256 | 0.258 | 0.261 | 0.2 |
| Copper | mg/l | 0.009 | 0.011 | 0.009 | 0.009 | 0.01 | 0.011 | 0.01 | 0.011 | 0.009 | 1 |
| Lead | mg/l | 0.074 | 0.11 | 0.083 | 0.079 | 0.088 | 0.126 | 0.0629 | 0.116 | 0.087 | 0.05 |
| Cadmium | mg/l | 0.052 | 0.053 | 0.05 | 0.049 | 0.041 | 0.049 | 0.051 | 0.051 | 0.048 | 0.003 |
| Zinc | mg/l | 0.077 | 0.042 | 0.043 | 0.074 | 0.052 | 0.047 | 0.04 | 0.061 | 0.057 | 3 |

### 4.2.1 pH

Water pH ranges from 4.65 to 5.83, and Station 3 has been reported as the most acidic. This propagates with the study by Chau and Jiang 2002, which agreed that natural water bodies are always slightly acidic because they normally originate from rain water and incorporate with acid released from the leaves of the forest within the area. Acid Mine Drainage (AMD) is also the contributing factor to the acidic condition of the water from the lake. The AMD is generated by the oxidation of sulfide bearing minerals exposed to weathering conditions, resulting in low quality effluents characterized by acidic pH, a high level of dissolved metals and anions (Razo et al. 2004).

### 4.2.2 Turbidity

The turbidity results of all water samples from the 3 station fells within the prescribed limit provided by Ministry of Health (MOH). It ranges from 1.14 NTU to 3.86 NTU and fall far below the limit set by MOH which is 1000 NTU. The highest turbidity recorded was in station 2 with the value of 3.86 NTU and could be caused by the presence of clay and other materials of soil observed in the lake. The variation of turbidity results might occur due to different agricultural or human activities that presence all around the sampling points.

### 4.2.3 Dissolved Oxygen (DO)

Dissolved Oxygen content in the water ranges from 10.30 mg/L to 10.89 mg/L and these results comply with the standard prescribed by the Ministry of Health, requiring the DO value to exceed 5.0 mg/L. According to the Guidelines for Drinking-water Quality, WHO, the DO content of water is influenced by the source, raw water temperature and chemical or biological processes taking place in the water.

### 4.2.4 Organic Pollutant

Water samples from the 3 stations reported a high COD value. The values ranged from 30 to 66 mg/L and these values are far above the limit prescribed by the MOH which is only 10 mg/L. The highest COD value detected was at station 2 with a value of 66 mg/L. This could be due to the discharge of agricultural wastes into the water, as the sampling location is surrounded by the palm oil plantations. Studies have proved that agricultural, industrial and domestic wastewater is considerable sources of high COD (Mthembu, M. S. et al, Effect of Agricultural and Industrial Developments on the Quality of Water at UMhlathuze River (Northern Coast of Kwa-Zulu Natal RSA), 2011).

### 4.2.5 Heavy Metals

Heavy metals are one of the issues often mentioned and discussed in studies related to water from ex-mining lakes. There are six (6) parameters of heavy metals that will be discussed in this study. The parameters are Iron, Zinc, Manganese, Copper, Lead, and Cadmium. **Figure 4.1** sums up the constituents of heavy metals ( Mn, Cu, Pb, Cd, Zn, and Fe) in the lake.

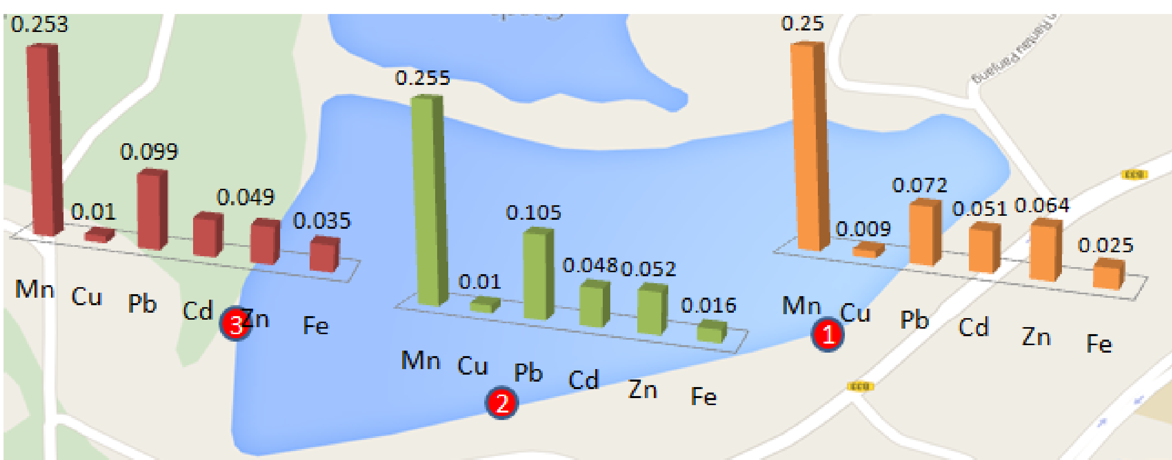


**Figure 4.1:** Constituents of heavy metals in the 3 stations

#### 4.2.5.1 Iron (Fe)

The concentration of Iron in all water samples from the ex-mining lakes are within the prescribed limits in the Drinking Water Quality Standard (Raw Water) that is issued by Ministry of Health (MOH), Malaysia. The value ranges from 0.002 mg/L to 0.049 mg/L and Station 3 recorded the highest concentration of Fe. According to the standard, the permissible value of Fe is 1.0 mg/L. Acid mine drainage can result locally in the precipitation of Fe or Mn ochres which may also contain significant concentrations of other metals (Muhammad et al. 2012.).

#### 4.2.5.2 Manganese (Mn)

The constituents of Mn in the water samples are slightly above the standard limits issued by MOH. It is reported that the concentrations of Mn in the water range from 0.24 mg/L to 0.26 mg/L. The results obtained exceed the limits by not more than 0.06 mg/L, as the permissible limits set by MOH is 0.20 mg/L. The high concentration of Mn in the water samples from the ex-mining lake indicated a natural origin of the elements in the lake sediment. Thus the presence of metal elements in the sediment suggested that it is originated from natural and anthropogenic input (Zaini Hamzah et al. 2011).

#### 4.2.5.3 Copper (Cu)

The concentration of Cu in the raw water samples from the ex-mining lake ranges from 0.009 mg/L to 0.011 mg/L in all three stations. The highest value recorded was 0.011 mg/L at various stations throughout the three consecutive sampling months. These results comply with the standard issued by MOH, which is 1.0 mg/L. According to the Guidelines for Drinking-water Quality, World Health Organization (WHO), Cu is not normally a raw water contaminant, which explains the low concentration of the element in the water samples.

### 4.2.5.4 Lead (Pb)

Pb concentration in all water samples ranges from 0.06 mg/L to 0.12 mg/L and the highest concentration recorded is at Station 3 during April. This propagates the findings by previous researches by Yap et al. (2009) and K. U Orji (2013). These results are slightly above the acceptable limits issued by MOH, which is 0.05 mg/L. High lead concentration can be found in surface water as a result of natural processes such as the absorption from the soil (WHO, Guidelines for Drinking-water Quality, 4th Edition).

According to the United States Environmental Protection Agency (USEPA), Pb may cause health problems if present in amounts greater than the drinking water standard. It may cause delays in physical or mental development in infants and children. Whereas the health effects for adults are that it causes kidney problems and high blood pressure.

### 4.2.5.5 Cadmium (Cd)

Cd concentration in all water samples collected from the ex-mining lake in Bestari Jaya ranges from 0.048 mg/L to 0053 mg/L. These results are far above from the acceptable limits issued by MOH, which is 0.003 mg/L. This can be due to the release of Cd to the environment in wastewater, and diffuse pollution is caused by contamination from fertilizers and local air pollution (WHO, Guidelines for Drinking-water Quality, 4th Edition).

According to WHO, in Cadmium for Drinking-water, fertilizers produced from phosphate ores constitute a major source of diffuse Cadmium pollution. The solubility of cadmium in water is influenced to a large degree by its acidity; suspended or sediment-bound cadmium may dissolve when there is an increase in acidity (Ros and Slooff, 1987). In natural waters, cadmium is found mainly in bottom sediments and suspended particles (Friberg et al., 1986).

Researchers agreed that Cadmium is generally classified as toxic trace element. It is found in very low concentration in most rocks, as well as in coal and petroleum and often in combination with Zinc. Geologic deposits of cadmium can serve as sources to groundwater and surface water, especially when in contact with soft, acidic waters (Hanaa, 2000).

#### 4.2.5.6 Zinc (Zn)

Zinc concentrations in the ex-mining lake ranges from 0.04 mg/L to 0.077 mg/L. These values range verily throughout the three stations and three consecutive samplings. The results obtained comply with the standard issued by MOH which requires the concentration of Zn to be less than 3.0 mg/L.

## 4.3 Coagulation Treatment Using Alum and Poly Aluminium Chloride (PAX-10)

Due to a high concentration of two types of heavy metals that do not comply with the standard issued by MOH, coagulation treatment using two types of coagulants is proposed to determine whether or not Cd and Pb can be removed by basic treatment of coagulation. Jar Test is run to the water samples to examine the efficiency of different types of coagulants namely Alum and Poly Aluminium Chloride (PAX-10). Coagulation is said to be efficient for removal of particulates and bound microorganisms, certain heavy metals and low-solubility organic chemicals (WHO, Guidelines for Drinking-water Quality, 4th Edition).

### 4.3.1 Lead (Pb) Removal

The post treatment results of Pb removal using Alum are listed in **Table 4.2**. The parameters involved include Turbidity and Pb concentration.

**Table 4.2:** Post treatment results of Pb removal using Alum

| Alum dosage (ppm) | Pb concentration (mg/l) | Turbidity | Percentage Removal (%) |
|---|---|---|---|
| 0 | 0.054 | 1.84 | 0 |
| 10 | 0.049 | 1.76 | 9.26 |
| 20 | 0.047 | 1.48 | 12.96 |
| 30 | 0.038 | 1.36 | 29.63 |
| 40 | 0.026 | 1.31 | 51.85 |

**Table 4.3** sums up the post treatment results of Pb removal using Poly Aluminium Chloride (PAX-10).

**Table 4.3:** Post treatment results of Pb removal using PAX-10

| PAX-10 (ppm) | Pb concentration (mg/l) | Turbidity | Percentage Removal (%) |
|---|---|---|---|
| 0 | 0.054 | 1.87 | 0 |
| 10 | 0.031 | 1.66 | 42.6 |
| 20 | 0.024 | 1.63 | 55.6 |
| 30 | 0.023 | 1.55 | 57.4 |
| 40 | 0.015 | 1.34 | 72.2 |

### 4.3.2 Alum versus PAX-10 in Removing Pb

There is a huge difference in percentage removal results of Pb for both types of coagulants. From the analysis, it is observed that PAX-10 has the ability to remove a large amount of Pb from water, up to 72.2% at 40 ppm dosage, compared to only 51.85% removal using Alum of the same dosage. Generally, the percentage removal of Pb from the lake water samples increased with the concentration of either types of coagulant used.

This proves that PAX-10 is more efficient in removing Pb from water compared to Alum. It was reported that Poly Aluminium Chloride or PAX-10 is more efficient for raw water that has low pH & alkalinity (Peter Gabbie, A Dummy's Guide to Coagulants). Taking into consideration that Alum might exhibit a certain health threat to human because of the Al ion in the coagulant; it is highly recommended that PAX-10 is used for water of similar characteristics.

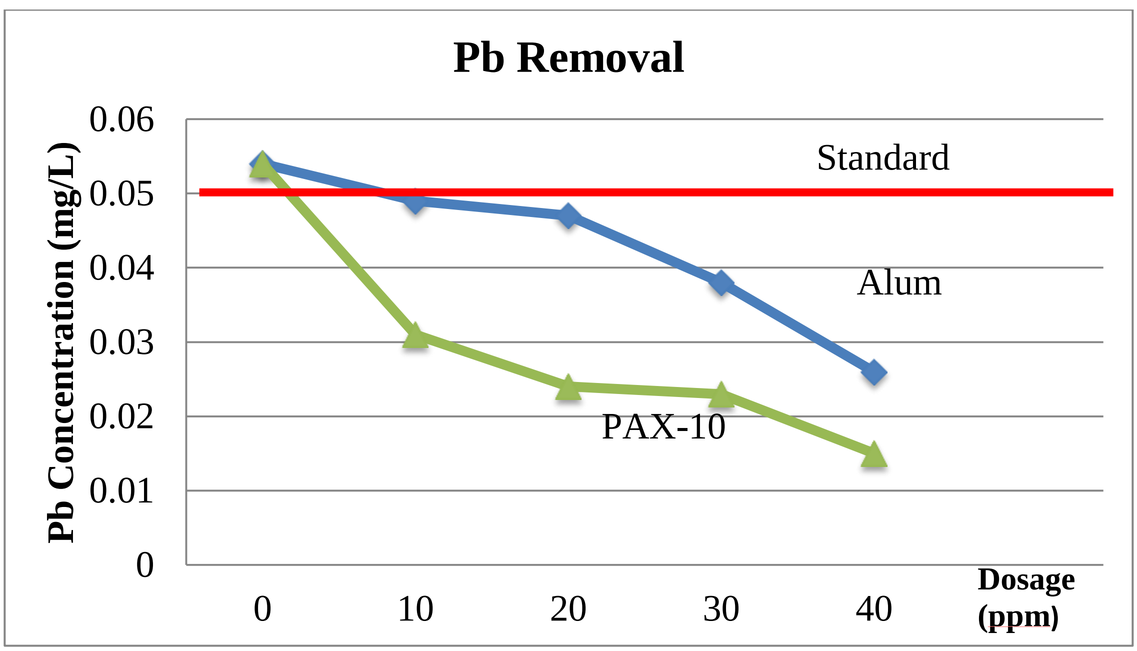


**Figure 4.2:** Comparison of Pb removal using Alum and PAX-10

### 4.3.3 Cadmium (Cd) Removal

The post treatment results of Cd removal using Alum are listed in **Table 4.4**. The parameters involved include Turbidity and Pb concentration.

**Table 4.4:** Post treatment results of Cd removal using Alum

| Alum dosage (ppm) | Cd concentration (mg/l) | Turbidity | Percentage Removal (%) |
|---|---|---|---|
| 0 | 0.1 | 1.84 | 0 |
| 10 | 0.091 | 1.76 | 10 |
| 20 | 0.089 | 1.48 | 11 |
| 30 | 0.087 | 1.36 | 12 |
| 40 | 0.081 | 1.31 | 19 |

**Table 4.5** sums up the post treatment results of Cd removal using Poly Aluminium Chloride (PAX-10).

**Table 4.5:** Post treatment results of Cd removal using PAX-10

| Alum dosage (ppm) | Cd concentration (mg/l) | Turbidity | Percentage Removal (%) |
|---|---|---|---|
| 0 | 0.1 | 1.87 | 0 |
| 10 | 0.088 | 1.66 | 12 |
| 20 | 0.087 | 1.63 | 13 |
| 30 | 0.083 | 1.55 | 17 |
| 40 | 0.080 | 1.34 | 20 |

**4.3.4 Alum versus PAX-10 in Removing Cd**

There is no significant difference of percentage removal of the two coagulants, but PAX-10 was reported to remove a higher concentration of Cd up to 20% compared to Alum at only 19% of removal using 40 ppm of coagulants respectively. It can be observed that the percentage removal is directly proportional to the coagulant dosage. The higher the dosage, the higher the percentage removal of Cd regardless of coagulant types used.

This proves that both types of coagulants are not really effective in removing Cadmium in water from ex mining lakes, but the use of PAX-10 is more preferable as it eliminates a higher amount of Cd from the water. Both coagulants may completely remove the concentration of Cd from the water but with higher dosage used. Considering that in the coagulation process, the percentage removal of Cd is highly affected by the coagulant dosage, hence it is recommended that PAX-10 is used since it produces less sludge than Alum as the by-product of coagulation process, when dosed at equivalent levels (Peter Gebbie, 2006).

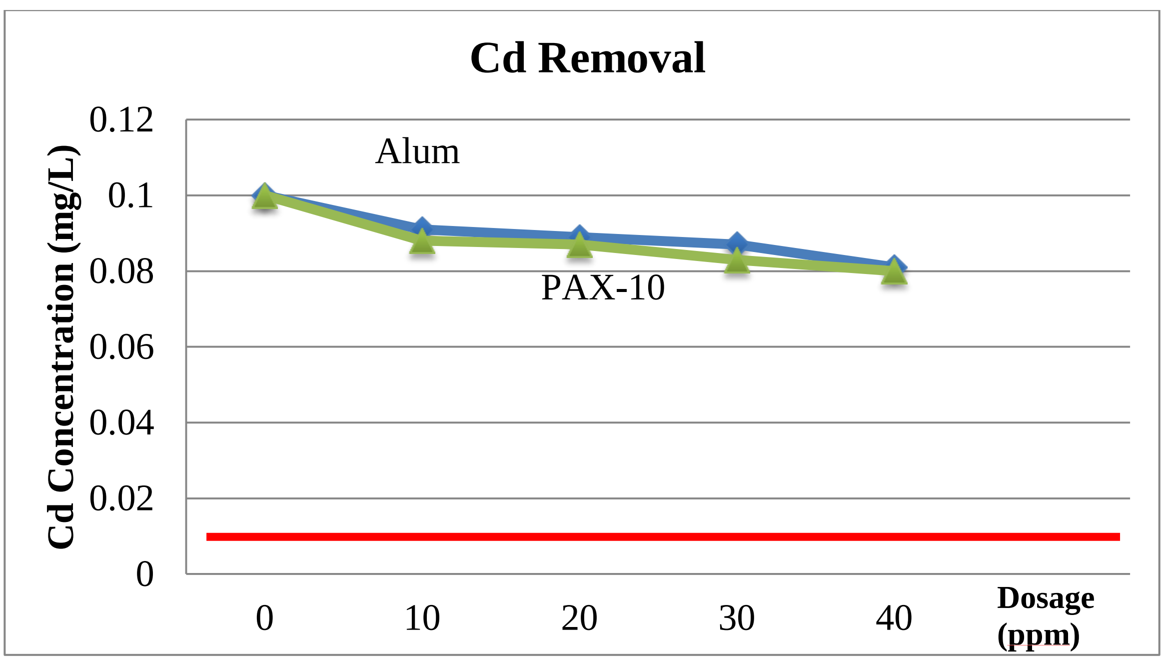


**Figure 4.3:** Comparison of Cd removal using Alum and PAX-10

# CHAPTER V

# CONCLUSIONS AND RECOMMENDATIONS

## 5.1 CONCLUSIONS

The water quality analysis prove that most parameters water from ex mining lakes comply with the standard of drinking water provided by the MOH. The summary and findings of the study are listed below:

i. Water from the ex-mining lakes can also be used for water supply after undergoing suitable treatments. It has the potential to be the alternative water source in Malaysia.

ii. The concentration of Pb and Cd that are slightly higher from the limits are proven can be reduced by further water treatment processes such as filtration and enhanced coagulation.

iii. It is observed that the most efficient type of coagulant to be used in treating water from ex-mining lakes is Poly Aluminium Chloride (PAX-10), as it is proven to remove more concentration of Pb and Cd compared to Alum. It is reported that PAX-10 has a better ability to treat raw water with low pH and alkalinity (Peter Gabbie, A Dummy's Guide to Coagulants).

## 5.2 RECOMMENDATIONS

For future research, more extensive studies could be carried out in order to have a better understanding and to see a clearer view of the characteristics and constituents of water from ex-mining lakes. Listed below are some recommendations that can be applied for future researches:

i. The research should be done in a more extensive duration or period of time to determine the effects of seasonal changes to the constituents of heavy metals in the ex-mining lakes.

ii. Water sampling from two or more different lakes should be collected to assess and compare the water quality from distinctive ex-mining lakes.

iii. Other types of coagulants should be considered in future research to observe the efficiency of coagulants in removing other elements of heavy metals from water of the ex-mining lakes.

**REFERENCES**


Abdullah A.M, Zaki Z., (2013). Sustainable River Water Quality Management in Malaysia.

C. K. Chang, A. AB. Ghani, (2008). Rehabilitation of Ex-Mining Pond and Existing Wetland for Integrated Stormwater Managemnet in 11th International Conference on Urban Drainage, Edinburgh, Scotland, UK, 2008.

David J. P. (2001). Drinking Water Coagulation with Poly Aluminium Coagulation Mechanisms and Selection Guidelines.

David B., Paul L. Y., Rolf T. A., Sheila B. B. (1996), Mine-water Chemistry: The Good, The Bad, and The Ugly.

Fares Y. A., Wan Z., Abdul R. S. , Esmail A. (2009). Risk Assessment at Abandoned Tin Mines in Sungai Lembing, Pahang, Malaysia.

Hanaa, M., Salem, Eweida, A., Azza F. (2000). Heavy Metals in Drinking Water and Their Environmetal impact on Human Health , 542-556.

International Council on Mining & Metals (ICMM), (2012). Water Managemnt in mining: A Slection of Case Studies.

K. U. Orji, N. Sapari, K. W. Yusof., ( 2013). Comparative Study of Water Quality of Rivers Used for Raw Water Supply & Ex-Mining lakes in Perak, Malaysia.

Laws of Malaysia, Act 233, (2012). Land and Mining Plans and Documents (Photographic Copies), Act 1950.

Lee C., Chon H. & Jung M. 2001 Heavy metal contamination in the vicinity of the Daduk Au-Ag-Pb-Zn mine in Korea. Apply Geochem 16: 1377–1386.

Muhammad, A. A., Mohd., J. M., and Ismail, B. Y. (2010). Study of Water Quality and Heavy Metals in Soil and Water of Ex-Mining Area of Jaya, Peninsular Malaysia 2010 Int. Journal of Basic & Applied Sciences.

Mohd Shahwahid H.O., Suhaimi A.R., R.M.K., (2007). Policies and Incentives for Rainwater Harvesting in Malaysia.

Ministry of Health (MOH) Malaysia, Engineering Services Division, Drinking Water Quality Surveillance Programme (2013).

OS Fatoki1 and AO Ogunfowokan, (2002), Effect of coagulant treatment on the metal composition of raw water

Peter G. (2005). A Dummy's Guide to Coagulants in 68th Annual Water Industry Engineers and Operators' Conference Schweppes Centre – Bendigo.

UNDP, Environmental Legislation for the Mining and Metals Industries in Asia, in United Nations Conference on Trade and Development, (1994).

United States Environmetal Protection Agency (USEPA), Water: Basic Information about Regulated Drinking Water Contaminants (2013).

World Health Organization (WHO) Guidelines for Drinking-Water Quality: 4th Edition, WHO Press, Geneva, Switzerland. (2011).

World Health Organization (WHO), Background document for development of

WHO Guidelines for Drinking-water Quality.

Yap, C. K., Fairuz, M. S., Yeow, K. L., Hatta, M. Y., Ismail, A., Ismail, A. R., and Tan, S. G. (2009). Dissolved Heavy Metals and Water Quality in the Surface Waters of Rivers and Drainages of West Peninsular Malaysia 2009 Asian Journal of Water, Environment and Pollution.

Zaki Z., (2010). Benchmarking River Water Quality in Malaysia.

## APPENDIX A1

## MOH DRINKING WATER QUALITY STANDARD

| **Parameter** | **Group** | **RECOMMENDED RAW WATER QUALITY** | **DRINKING WATER QUALITY STANDARDS** |
|---|---|---|---|
| | | **Acceptable Value (mg/litre (unless otherwise stated))** | **Maximum Acceptable Value (mg/litre (unless otherwise stated))** |
| Total Coliform | 1 | 5000 MPN / 100 ml | 0 in 100 ml |
| *E.coli* | 1 | 5000 MPN / 100 m | 0 in 100 m |
| Turbidity | 1 | 1000 NTU | 5 NTU |
| Color | 1 | 300 TCU | 15 TCU |
| pH | 1 | 5.5 - 9.0 | 6.5 - 9.0 |
| Free Residual Chlorine | 1 | - | 0.2 - 5.0 |
| Combined Chlorine | 1 | - | Not Less Than 1.0 |
| Temperature | 1 | - | - |
| Clostridium perfringens (including spores) | 1 | - | Absent |
| Coliform bacteria | 1 | - | - |
| Colony count 22° | 1 | - | - |
| Conductivity | 1 | - | - |
| Enterococci | 1 | - | - |
| Odour | 1 | - | - |
| Taste | 1 | - | - |
| Oxidisability | 1 | - | - |
| Total Dissolved Solids | 2 | 1500 | 1000 |
| Chloride | 2 | 250 | 250 |
| Ammonia | 2 | 1.5 | 1.5 |
| Nitrat | 2 | 10 | 10 |
| Ferum/Iron | 2 | 1.0 | 0.3 |
| Fluoride | 2 | 1.5 | 0.4 - 0.6 |
| Hardness | 2 | 500 | 500 |
| Aluminium | 2 | - | 0.2 |
| Manganese | 2 | 0.2 | 0.1 |
| Chemical Oxygen Demand | 2 | 10 | - |
| Anionic Detergent MBAS | 2 | 1.0 | 1.0 |

| Parameter | Group | RECOMMENDED RAW WATER QUALITY | DRINKING WATER QUALITY STANDARDS |
|---|---|---|---|
| | | Acceptable Value (mg/litre (unless otherwise stated)) | Maximum Acceptable Value (mg/litre (unless otherwise stated)) |
| Biological Oxygen Demand | 2 | 6 | - |
| Nitrite | 2 | - | - |
| Total organic carbon (TOC) | 2 | - | - |
| Mercury | 3 | 0.001 | 0.001 |
| Cadmium | 3 | 0.003 | 0.003 |
| Arsenic | 3 | 0.01 | 0.01 |
| Cyanide | 3 | 0.07 | 0.07 |
| Plumbum/Lead | 3 | 0.05 | 0.01 |
| Chromium | 3 | 0.05 | 0.05 |
| Cuprum/Copper | 3 | 1.0 | 1.0 |
| Zinc | 3 | 3 | 3 |
| Natrium/Sodium | 3 | 200 | 200 |
| Sulphate | 3 | 250 | 250 |
| Selenium | 3 | 0.01 | 0.01 |
| Argentum | 3 | 0.05 | 0.05 |
| Magnesium | 3 | 150 | 150 |
| Mineral Oil | 3 | 0.3 | 0.3 |
| Chloroform | 3 | - | 0.2 |
| Bromoform | 3 | - | 0.1 |
| Dibromoklorometana | 3 | - | 0.1 |
| Bromodiklorometana | 3 | - | 0.06 |
| Fenol/Phenol | 3 | 0.002 | 0.002 |
| Antimony | 3 | - | 0.005 |
| Nickel | 3 | - | 0.02 |
| Dibromoacetonitrile | 3 | - | 0.1 |
| Dichloroacetic acid | 3 | - | 0.05 |
| Dichloroacetonitrile | 3 | - | 0.09 |
| Trichloroacetic acid | 3 | - | 0.1 |
| Trichloroacetonitrile | 3 | - | 0.001 |
| Trihalomethanes - Total | 3 | - | 1.00 |
| Aldrin / Dealdrin | 4 | 0.00003 | 0.00003 |
| DDT | 4 | 0.002 | 0.002 |

| Parameter | Group | RECOMMENDED RAW WATER QUALITY | DRINKING WATER QUALITY STANDARDS |
|---|---|---|---|
| | | **Acceptable Value (mg/litre (unless otherwise stated))** | **Maximum Acceptable Value (mg/litre (unless otherwise stated))** |
| Heptachlor & Heptachlor Epoxide | 4 | 0.00003 | 0.00003 |
| Methoxychlor | 4 | 0.02 | 0.02 |
| Lindane | 4 | 0.002 | 0.002 |
| Chlordane | 4 | 0.0002 | 0.0002 |
| Endosulfan | 4 | 0.03 | 0.03 |
| Hexachlorobenzena | 4 | 0.001 | 0.001 |
| 1,2-dichloroethane | 4 | - | 0.03 |
| 2,4,5-T | 4 | - | 0.009 |
| 2,4,6-trichlorophenol | 4 | - | 0.2 |
| 2,4-D | 4 | 0.03 | 0.03 |
| 2,4-DB | 4 | - | 0.09 |
| 2,4-dichlorophenol | 4 | - | 0.09 |
| Acrylamide | 4 | - | 0.0005 |
| Alachlor | 4 | - | 0.02 |
| Aldicarb | 4 | - | 0.01 |
| Benzene | 4 | - | 0.01 |
| Carbofuran | 4 | - | 0.007 |
| MCPA | 4 | - | 0.002 |
| Pendimethalin | 4 | - | 0.02 |
| Pentachlorophenol | 4 | - | 0.009 |
| Permethrin | 4 | - | 0.02 |
| Pesticides | 4 | - | - |
| Pesticides - Total | 4 | - | - |
| Polycyclic aromatic hydrocarbons | 4 | - | - |
| Propanil | 4 | - | 0.02 |
| Tetrachloroethene and Trichloroethene | 4 | - | - |
| Vinyl chloride | 4 | - | 0.005 |
| Gross alpha (α) | 5 | 0.1Bq/l | 0.1Bq/l |
| Gross beta (β) | 5 | 1.0 Bq/l | 1.0 Bq/l |
| Tritium | 5 | - | - |
| Total indicative dose | 5 | - | - |

# APPENDIX A2

## COMMONLY AVAILABLE COAGULANTS AND DETAILS

| COMMON COAGULANT NAME[1] | TYPICAL MANUFACTURERS | CHEMICAL NAME & FORMULA | TYPICAL ANALYSIS | NOTES | INDICATIVE COST. $/tonne (as 100%)[2] |
|---|---|---|---|---|---|
| Alum | Aluminates<br>Omega Chemicals | Aluminium sulphate<br>$Al_2(SO_4)_3.18H_2O$ | 7.5-8% $Al_2O_3$ or 49-52% w/w $Al_2(SO_4)_3.18H_2O$<br>SG 1.3 | Most common coagulant used in water treatment. Relatively cheap. | 450 |
| *PAC 23*<br>*MEGAPAC 23*<br>*ALCHLOR AC*<br><br>*PROFLOC A23* | Aluminates<br>Omega Chemicals<br>Hardman Chemicals<br>Orica/ Spectrum | Aluminium chlorohydrate (ACH)<br>$Al_2(OH)_5Cl$ | 23-24% $Al_2O_3$ or 40-41% w/w ACH<br>SG 1.33<br>83-84% basicity<br>8.5% w/w Cl | Used in lieu of alum where raw water has low pH & alkalinity. Has little impact on pH. | 2100 |
| *PAC-10 LB*<br>*MEGAPAC 10* | Aluminates<br>Omega Chemicals | Polyaluminium chloride (PACl)<br>$Al_2(OH)_3Cl_3$ | 10-11% $Al_2O_3$ or 20-23% w/w PACl. SG 1.18<br>50% basicity<br>10.5% w/w Cl | Used in lieu of alum where raw water has low pH & alkalinity. Has greater impact on pH than ACH. | 2500 |
| *PAC-10 HB* | Aluminates | Aluminium chlorohydrate (ACH) | Diluted ACH.<br>10% $Al_2O_3$<br>80% basicity | See ACH.<br>Sometimes used in small WTP's. | 2800 |
| PACS | Aluminates | Polyaluminium chlorosulphate<br>$Al_3(OH)_{4.95}Cl_{3.55}(SO_4)_{0.25}$ | 10% $Al_2O_3$ or 5.3% w/w Al SG 1.19<br>50% basicity<br>10% w/w Cl<br>2% w/w $SO_4$ | Aluminium-based coagulant. Not commonly used; at some NSW WTP's. | 2800 |
| *PASS*® | Aluminates | Polyaluminium silicosulphate<br>$Al_2(OH)_{3.24}Si_{0-1}(SO_4)_{1.38}$ | 10% $Al_2O_3$ or 5.3% w/w Al<br>SG 1.34<br>54% basicity | Strange coagulant! Cannot be diluted with water: forms flocs. Gippsland Water has used with success. | 2500 |
| Sodium aluminate | Aluminates | $NaAl(OH)_4$ | 18% w/w $Al_2O_3$ or 41.7% w/w $NaAl(OH)_4$<br>SG 1.47<br>12% w/w free NaOH | Strong alkaline coagulant. Can work on highly coloured water with low alkalinity. Used at some Tasmanian WTP's. | 2200 |
| *PFS*® | Aluminates | Polyferric sulphate<br>$Fe_2(OH)_{0.6}(SO_4)_{2.7}$ | 12.2% w/w Fe(III) or 43.7% w/w $Fe_2(SO_4)_3$<br>SG 1.54<br>10% basicity | Hydroxylated ferric sulphate. Used at several WTP's in NSW. | 650 |
| Ferric Sulphate<br>*MEGACLEAR 12* | Hardman<br>Omega Chemicals | Ferric sulphate $Fe_2(SO_4)_3$ | 12% w/w Fe(III) or 43% w/w $Fe_2(SO_4)_3$ SG 1.50 | Similar to *PFS*®. Has greater impact on raw water pH. | 550 |
| *PROFLOC F* | Orica/ Spectrum | Ferric chloride<br>$FeCl_3$ | 14-15% w/w Fe(III) or 41-43% w/w $FeCl_3$<br>SG 1.45 | Similar to other ferric coagulants. No $SO_4$ added to treated water. Very corrosive. | 1400 |