

**STUDY OF WELL WATER QUALITY AND HEAVY
METAL CONTENT IN URBAN AND RURAL AREA:
CASE STUDY AT KOTA BHARU AND PASIR
PUTEH, KELANTAN**

by

NORISHAH BINTI ABD TALIB

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LIST OF ABBREVIATIONS AND SYMBOLS

BOD	Biochemical oxygen demand
COD	Chemical oxygen demand
DO	Dissolved oxygen
DOE	Department of Environment
df	degree of freedom
GPS	Global Positioning System
INWQS	Interim National Water Quality Standard
MOH	Ministry of Health
mg/L	milligrams per Litre
NH ₃ -N	Ammonical nitrogen
sd	Standard deviation
SPSS	Statistical Package for the Social Sciences
SS	Suspended Solids
USEPA	United State Environmental Protection Agency
WHO	World Health Organization
WQI	Water Quality Index

**STUDY OF WELL WATER QUALITY AND HEAVY METAL CONTENT IN
URBAN AND RURAL AREA: CASE STUDY AT KOTA BHARU AND PASIR
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ABSTRACT

Groundwater quality whether at urban or rural area can be influenced by natural factors and anthropogenic activities. Urbanisation, agriculture and industrial are examples of anthropogenic activities while interactions of rocks, soils, natural disasters are natural factors that can influence quality of groundwater. In this study, a total number of 60 water samples were collected from wells at urban and rural area. Water sample were analysed for water quality and heavy metal parameters. The results were compared to standard drinking water by Ministry of Health (MOH) and Interim National Water Quality Standard (INWQS) for classification of Water Quality Index (WQI) value. Result indicates that well water quality of sampling locations was classified to class III. The value for each parameter are in the range of 4.44 - 7.7 mg / L, 1.0-3.8 mg / L, 4.7-60 mg / L, 0.01- 1.0 mg / L, 0.7- 13.7 mg / L, 4.3-8.0 for DO, BOD, COD, NH₃N, SS and pH respectively and undetected to 3.9 mg / L, undetected to 0.005mg / L, 0002-0009 mg / L, 0001 -0009 mg / L for Fe, Cd, Mn and Pb content respectively. Comparison of water quality and heavy metals parameters between Kota Bharu and Pasir Puteh was carried out using an independent t-test. The results showed significant differences between the two areas, with $p < 0.05$ except for both Fe and Mn which showed $p > 0.05$.

Keywords: urban, rural, anthropogenic, natural, WQI, heavy metal

**KAJIAN KUALITI AIR PERIGI DAN KANDUNGAN LOGAM BERAT DI
KAWASAN BANDAR DAN LUAR BANDAR: KAJIAN KES DI KOTA BHARU
DAN PASIR PUTEH, KELANTAN.**

ABSTRAK

Kualiti air bawah tanah sama ada di kawasan bandar atau luar bandar boleh dipengaruhi oleh faktor semula jadi dan aktiviti antropogenik. Perbandaran, pertanian dan industri adalah contoh aktiviti antropogenik manakala interaksi batuan, tanah, bencana alam adalah faktor semula jadi yang boleh mempengaruhi kualiti air bawah tanah. Dalam kajian ini, sebanyak 60 sampel air telah diambil dari air perigi di kawasan bandar dan luar bandar. Sampel air dianalisis untuk parameter kualiti air dan logam berat. Hasil yang diperolehi dibandingkan dengan standard kualiti air minuman yang ditetapkan oleh Kementerian Kesihatan Malaysia (KKM) dan Interim Standard Kualiti Air Kebangsaan (INWQS) untuk pengkelasan nilai Indeks Kualiti Air (IKA). Hasil kajian mendapati air dari lokasi persampelan berada pada kelas III. Nilai julat bagi setiap parameter berada pada lingkungan 4.44 – 7.7 mg/L, 1.0-3.8 mg/L, 4.7- 60 mg/L, 0.01- 1.0 mg/L, 0.7- 13.7 mg/L, 4.3- 8.0, masing-masing untuk oksigen terlarut, permintaan oksigen biokimia, permintaan oksigen kimia, ammonia nitrogen, pepejal terampai, pH. dan 0-3.9 mg/L, 0-0.005mg/L, 0.002–0.009 mg/L, dan 0.001 -0.009 mg/L masing-masing untuk ferum, cadmium, mangan dan plumbum. Perbandingan parameter kualiti air dan logam berat di antara kawasan Kota Bharu dan Pasir Puteh telah dijalankan dengan menggunakan ujian t-bebas. Keputusan menunjukkan perbezaan yang signifikan diantara kedua-dua kawasan dengan nilai $p < 0.05$ kecuali logam berat ferum dan mangan.yang menunjukkan nilai $p > 0.05$.

Kata kunci: bandar, luar bandar, semula jadi, antropogenik, Indeks Kualiti Air, logam berat

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Water is the most valuable natural resource on our planet. There could be no life on earth without water. Water makes up two-thirds of our bodies and humans can live only a few days without it (Monroe *et al.*, 2003).

Water has been widely used in the sectors of industry, transportation, and agriculture as well as energy generation. As human population increases, the production rate of food stocks, follows with evolving industry make water resource becomes more critical. The increases also influenced the demand for fresh water. In the last few decades, there has been a tremendous increase in the demand for fresh water due to rapid growth of population and the accelerated pace of industrialisation (Ramakrishnaiah, Sadashivaiah and Ranganna, 2008).

The most important fresh water source in the world, based on stability and importance is groundwater (Cristina, Iona, Mihaela and Ildiko, 2003). Groundwater constitutes about 95 per cent of the freshwater on our planet and making it fundamental to human life and economic development. Many people around the world depend on groundwater in their life. As evident by the fact that, over half of the population in twenty-three cities of the world which had a population of more than 10 million, rely upon or make significant use of local groundwater. Besides, two-thirds of water supply from more than 500 cities in China is drawn from aquifers, while almost a third of the largest cities of Russia meet

their water demands mainly from groundwater as do many of the capitals of central and West African countries. It is estimated that almost one-third drinking water supply in Asia comes from groundwater and more than 95 per cent of the rural populations in USA depend on aquifers to provide their drinking water. (Morris *et al.* , 2003).

In Malaysia, groundwater contributes 3.0 per cent of water supply. According to Department of Water Supply (2005-2006) and National Water Services Commission (2007-2009), groundwater is a second major source of water supply in Kelantan compare to other states. People in Kelantan use groundwater more than 70% for their water supply (Department of Statistic Malaysia, 2009).

Groundwater is delivered to the point of use or user by wells. The reason why people use groundwater is due to its ease of use and cheap. It is a resource that is organizationally easy to develop. Individuals can construct, operate and control their own supply, often on their own land (Morris *et. al.*, 2003).

Although groundwater is more protected than surface water, it still can be polluted. The degree of degradation of groundwater quality depends on both natural and anthropogenic activities. The major anthropogenic activities for continuous groundwater quality deterioration include urbanisation, industrialisation and agriculture run off (Rajankar, Tambekar and Wate, 2010). Degradation of urban groundwater could be accelerated in highly commercial and residential areas besides industrial sites. On the other hand, agricultural activities can contribute to deterioration of suburban and rural groundwater.

As groundwater become water resources for human consumption, its quality should be assessed to determine whether the water is suitable for use. The quality of water can be measured by assessing its physicochemical and biological properties against a set of standards. Water can be defined as polluted when they are changes in it quality in term of composition of chemical, physical and biological characteristics until it's not suitable as drinking water as well as habitat for aquatic life, irrigation for agriculture, recreation and so on (Khatri and Tyagi, 2014).

The important technique for demarcating water quality including groundwater for various purposes is by using water quality index (WQI). WQI is defined as a technique of rating that provides the composite influence of individual water quality parameters on the overall quality of water for human consumption (Rizwan and Singh, 2010). The overall parameters of water that are measured are classified into classes' accordance to water standard.

In spite of it, heavy metal also can be measured for measuring water quality. Heavy metal can be present in groundwater due to human activities. Excessive level of heavy metal in drinking water may become health problem to user.

Drinking water that is good quality is of basic needs to human physiology. In order to prevent health hazard, the provision of potable water to the rural and urban population is necessary. The properties of water that people use as potable water should include low organic content, pH value near neutrality, free from excessive amount of infectious

agents, toxic substances and chemical substances such as heavy metal (Kerketta, Baxla, Gora, Kumari and Roushan, 2013).

1.2 PROBLEM STATEMENT

There is a problem in distribution of water supply in Kelantan. No coverage by Air Kelantan Sdn Bhd (AKSB) and frequent disruptions of water services make people use private well as their water sources. These water sources that obtained by their own, generally are not treated by public agency. Consequently, the qualities of water that people consume are unknown and they might be exposed to poor water quality in term of physical, biological and chemical properties.

Despite people boiled the water before used, it still insufficient to eliminate the contaminants that present. The water should posses some treatment to reduce the contaminants and in order to ensure the quality of water. However, since there is no treatment and monitoring that are conducted, it might negatively; impacted health of people.

A possible cause of this problem is natural occurring and human activities at the surrounding areas. The location of well that nearby the sources of pollution will decreased the level of water quality. In urban area, the quality become worst as increasing population, residential, commercial and industrial activities while agriculture activities at suburban and rural area make the water quality decreased.

A study which investigates the well water quality and heavy metal content could remedy the situation. People will know their water quality status and in the other hands, they will take a proper action regarding the problems.

1.2 OBJECTIVE

1.3.1 General objective

This study aims to study well water quality status at urban and rural area.

1.3.2 Specific objectives

- To study well water quality status at Kota Bharu and Pasir Puteh area accordance to water quality index and heavy metal parameters and compare it with standard drinking water
- To determine WQI value of well water at Kota Bharu and Pasir Puteh area
- To compare well water quality and heavy metal status at Kota Bharu and Pasir Puteh area

1.3 HYPOTHESIS

1.4.1 Alternative Hypothesis

There is significant difference of well water quality at Kota Bharu and Pasir Puteh area

There is significant difference of heavy metal at Kota Bharu and Pasir Puteh area

1.4.2 Null Hypothesis

There is no significant difference of water quality at Kota Bharu and Pasir Puteh area

There is no significant difference of heavy metal at Kota Bharu and Pasir Puteh area

1.4 SIGNIFICANT OF STUDY

- ▶ The findings of this research may provide the status and level of heavy metal in well water at Kota Bharu and Pasir Puteh
- ▶ The findings of this research also may provide well water quality status by WQI value
- ▶ The findings of this research may useful for the user to know their water quality level
- ▶ The data that are finding may useful for the future planning for improvement

CHAPTER 2: LITERATURE REVIEW

2.1 GROUNDWATER

Groundwater is the water found underground in the cracks and spaces in soil, sand and rock. It is a part of the Earth's water or hydrological cycles. When rain falls, a part infiltrates the soil and the remainder evaporates or runs off into rivers. The roots of plants will take up a proportion of this moisture and then lose it through transpiration to the atmosphere, but some will infiltrate more deeply and lastly forming an underground reservoir (Morris *et al.*, (2003).

As groundwater is delivered to the point of use or user by wells, the major of concern is the design of a well in order to prevent contaminants from entering the aquifer. The construction of well must be conduct at the area that free from any pollution sources which can lead to decreasing in water quality (Monroe *et al.*, 2003).

2.2 FACTOR THAT AFFECT GROUNDWATER QUALITY

Groundwater quality whether in urban or rural area are largely determined by the natural processes and anthropogenic activities (Devic, Djordjevic and Sakan, 2014). Process such as groundwater velocity, quality of recharge waters, interaction of water with soil and rock, and interaction with other types of aquifers are example of natural process which can affect groundwater quality, while for anthropogenic activities like agriculture,

industry, and urban development are example of activities that can influence groundwater quality (Jiang, Wu, Groves, Yuana and Kambesis, 2009).

2.3 MECHANISM OF GROUNDWATER CONTAMINATION

2.3.1 Mechanism of groundwater contamination at urban area

With the rapid economic growth and fast population increase, land use has become one of the most important factors that are responsible for groundwater quality. Various anthropogenic activities under the shadow of urbanisation and the industrial development results in effluent disposal, which introduced into the groundwater system and lead to high contaminants in groundwater (Devic, Djordjevic and Sakan, 2014). Products and wastes from nearby factories, industrial plants and even small business such as gas stations and dry cleaners can threaten ground water supplies due to spills, leaking underground tanks and piping and improper disposal. Improper disposal of household waste like cleaning solvents, used motor oil, paints, paint thinners, soaps and detergent can pollute groundwater due to faulty septic tanks (USEPA, 2012).

Normally the contaminants are introduced into groundwater system either discharged to the ground by factories, warehouse or households and then migrate to the subsurface together with rainwater infiltration or they can be directly discharge into subsurface soil layer through leaking of sewer pipes (Khatri and Tyagi, 2014).

Heavily traffic and transport at urban area also can potentially contribute to degradation of groundwater quality. A large of emissions of organic and inorganic substances from traffic setting which include roads, airfields, railway lines, inland waterway transportation may reach soils and some these may reach groundwater. Other than that, transport installation and facilities especially petrol station, airfields, abandoned vehicles also may be substantial points sources of groundwater pollution (Schmoll, Howard, Chilton and Chorus, 2006).

Besides, in suburban areas where agricultural land or livestock farms exist, pollution by nitrogen, pathogenic microorganism by fertilizers and livestock wastewater can sometimes found in significant levels in groundwater (Khatri and Tyagi, 2014). In other hands, heavy metal contaminant also can be present due to excessive use of fertilizer or pesticides at the area.

2.3.2 Mechanism of groundwater contamination at rural area

For rural area, there are several sources that can degrade groundwater quality and agricultural run-off is one of the nonpoint sources of pollution that can deteriorate groundwater quality. Examples of agricultural activities that can cause pollution include poor animal husbandry practices, excessive use of pesticides and fertilizers which can contribute to highly in ammonia and nitrate as well as heavy metal (Khatri and Tyagi, 2014).

Many fertilizers contain forms of nitrogen that can break down into harmful nitrates and this could add to other sources of nitrates in groundwater. It potentially ends up in groundwater resource. Besides, some underground agricultural drainage systems collect fertilizers and pesticides which can introduce organic and inorganic pollutants into the water system and lastly can pose problems to ground water (USEPA, 2012).

2.4 PREVIOUS STUDIES

2.4.1 Oversea research

Groundwater meets over 75% of the water needs in many countries over the world. In many nations, more than half of the withdrawn groundwater is for domestic water supplies and globally it provides 25 to 40 % of the world's drinking water (Vrba and Gun, 2004). In India groundwater acts as a major source of drinking water for urban and rural area (Singh, Jain and Mohan, 2013) in spite of other region such as Asia- Pacific, Europe, Central and South America, USA, Australia (Morris *et al.*, 2003).

However, groundwater can suffer from many kinds of contamination from both natural and anthropogenic as well as point and non-points sources. Examples of contaminants that can be found are organic, inorganic and also heavy metal. Mile, Amonum and Sambe (2013), had conducted a study about heavy metal pollution of groundwater in urban and suburban areas of Makurdi Metropolis, Nigeria. Water sample are collected from 15 wells for each urban and suburban area according to political wards. In this study, the result indicates that the concentration of heavy metal like cadmium, and iron in the well water are above WHO standard and the water must be boiled or treated

through reverse osmosis before use. The presence of iron in the well water are due to low pH or indiscriminate use of agricultural chemical while cadmium may be attributed to runoff from wastes, batteries and paints since the mechanic village is located at the area.

A study about assessment of groundwater for heavy metals in selected areas of North Lebanon had conducted by Tannous, Haddad and Jabbour in 2013. In this study, 54 groundwater samples are collected from three different regions which were Bcharreh, a high mountain area, the region of Bessebaal, a semi industrial area and the region of Chekka, highly industrial area. Four heavy metals were analyze and the result showed that the mean concentration of heavy metal were generally higher in industrial region than in non-industrial region. The presence of Cr in drinking groundwater could be due to numerous uses of wood preservation, chemical industry, dyes production, lather tanning or even chrome plating. The highest level of Pb also at industrial region and it could be mainly due to local industries contamination or burning leaded fuel. However the detection of copper was below the permissible limit while zinc was exceeding the limit at the most regions.

In spite of assessment heavy metal in groundwater, water quality index (WQI) also is another technique for determining groundwater quality for various purposes including water for human consumption. A study about assessment of groundwater quality status by using WQI method in Orissa, India had been conducted by Reza and Singh, 2010. The water samples in this study were collected from twenty four wells and sampling location was selected based on industrial and different land use pattern area. Ten

parameters like pH, turbidity, total dissolved solid, total hardness, Cl^- , NO_3^- , F^- , Fe , Mg^{++} and Ca^{++} were analyzed for WQI. The result from this study indicated that groundwater samples were found in the range of good category and a few location were exceeds the permissible WQI limit 50 and needs some degree of treatment before consumption.

A study about assessment of groundwater quality status by using WQI method in Tureni Village, Cluj Country had conducted by Cristina *et al.* in 2011. 120 water samples were collected from different wells in the village of Tureni for three months. In this study, eight important parameter like pH, electrical conductivity, total dissolved solid, magnesium, chloride, sulfate and nitrate were analyzed for calculation of water quality index. The result from this study shows that WQI calculation of the water from the wells from Tureni, presenting high values which were more than 100 and it represents that the water cannot be consumed as drinking water.

2.4.2 Local state research

Groundwater quality status in Malaysia was determined based on National Guidelines for Raw Drinking Water Quality from Ministry of Health. In 2010, water samples from 121 monitoring wells in Malaysia which were divided into several categories of land use as mentioned in table 2.1 are analysed for heavy metals and the result showed that Fe and Mn level in all categories exceed the allowance limit for standard drinking water. Cd and Pb also exceed the guideline value but in certain categorical only (Environmental Quality Report, 2010).

Table 2.1: Percentage of several heavy metals that exceed the allowance limit of drinking water

Categories	Fe (mg/L)	Mn (mg/L)	Cd (mg/L)	Pb (mg/L)
Agriculture	63	37	5	3
Urban/suburban	64	56	0	0
Rural	38	38	0	0
Industrial	89	46	0	0

Sources: adopted from Environment Quality Report 2010

A study about status of groundwater contamination in rural area, Kelantan was conducted by Idrus, Fauziah, Hani, Rohaila and Mansor in 2014. 454 sampled wells were collected from nine districts which were Bachok, Kota Bharu, Tumpat, Pasir Mas, Pasir Puteh, Machang, Tanah Merah, Kuala Krai, and Gua Musang. In this study, chemical and microbiological parameters were analyzed and the result showed that some samples contained microbiological and chemical pollutants. Ferum was highly detected in Bachok followed by Pasir Puteh, Kota Bharu, Kuala Krai, Machang, Gua Musang Pasir Mas and Tanah Merah. High levels of Manganese were detected more frequently in Kuala Krai, Gua Musang, Kota Bharu, Machang, Bachok, Tumpat, Pasir Mas, Pasir Puteh and Tanah Merah. Violation of ammonia only detected at five districts which are Tumpat, Gua Musang, Kota Bharu, Pasir Puteh and Bachok.

WQI in Malaysia were determined based on six parameter which are pH, biochemical oxygen demand, chemical oxygen demand, ammoniacal nitrogen, dissolved oxygen and suspended solid. The calculation from this parameter will classify the water into several classes. Based on table 2.2, there are several classes of water quality starting from 1 to V. From the classes, the uses of water can be classified whether it can be consumed by human with, without treatment or cannot consume at all as mention in Table 2.3.

Table 2.2: Water Quality Index (WQI) Classification

	CLASS				
WQI	I	II	III	IV	V
	< 92.7	76.5-92.7	51.9 -76.5	31.0 -51.9	> 31.0

Sources: Adopted from Environmental Quality Report, 2006

Table 2.3: Water Classes and Uses

CLASS	USESS
Class I	Water supply I- Practically no treatment necessary
Class IIA	Water supply II – Conventional treatment
Class III	Water supply III – Extensive treatment required
Class IV	Irrigation
Class V	None of the above

Sources: Adopted from Environmental Quality Report, 2006

2.5 PROBLEMS INVOLVING CONTAMINANTS

Some metals such as Fe, Mn, Cu and Zn are essential for living organisms at low concentrations. However toxic effects are observed when concentrations are increase (Makkasap and Satapanajaru, 2010). Normally Fe is only slightly toxic but excessive intake can cause siderosis and damage to organs though excessive iron storage. Iron in higher concentration may also cause vomiting but its deficiency may causes anemia and shortness of breath. High concentration of iron in water also can lead to liver diseases (Deshmukh, 2013). Although the incidence of Mn toxicity is rare because Mn is rapidly excreted in the kidney; however, high concentration of Mn was associated with permanent damage, symptoms of impaired neurological and neuromuscular control, mental and emotional disturbances, muscle stiffness, lack of coordination, tremors, difficulties with breathing or swallowing, and other neuromuscular problems (USEPA, 2007).

Besides, Cd and Pb are common heavy metals which humans are exposed to. Cadmium may cause diseases including hypertension, arteriosclerosis, cancer and etc. It also may result to kidney damage if excess in drinking water over time (Mile, Amonum and Sambe, 2013). Pb also can give problems to human. It is a toxin and probably human carcinogen. It may result in autoimmunity in which immune system of the body attacks its own cells. This might cause the development of joint diseases and malfunction of kidneys, cardiovascular system and neurons. It also can cause permanent brain damages at higher concentration (Pirsaheb, Khosravi, Sharafi, Babajani and Rezaei, 2013).

Other than heavy metal, organic contaminants and nitrogen species also can give health effect to consumer. Some organic contaminants can cause cancer, birth defect and damage to the nervous system (Honqi, Shuyuan and Shasha, 2013), while nitrogen species such as nitrite may cause blue baby syndrome to infants (Schmoll, Howard, Chilton and Chorus. 2006.)

CHAPTER 3: METHODOLOGY

3.1 INTRODUCTION

The purpose of this research was to study the well water quality at Kota Bharu and Pasir Puteh area according to WQI and heavy metals. It consist measuring of 10 parameter which were pH, total suspended solid, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammoniacal nitrogen (NH₃-N), Mn, Cd, Pb, and Fe.

3.2 STUDY LOCATION

This research was conducted at Kota Bharu and Pasir Puteh area. Kota Bharu and Pasir Puteh were chosen as sampling area due to classification of urban and rural area for Kelantan state. Kota Bharu is a capital for Kelantan state which consists of 15 districts and covers an area of 409 kilometer per square (Land and District Office of Kota Bharu, 2014).

Besides, Pasir Puteh consists of 8 districts and covers an area approximately 43 368.84 hectares/433.8 km per square. It was one of the rural areas in Kelantan due to agricultural activities which covered 82% total area of Pasir Puteh (Land and District Office of Pasir Puteh, 2014).

30 sampling location for Kota Bharu and Pasir Puteh area was decided due to well water that villagers used for their routine activities. The sampling locations were chosen due to location that potentially may degrade their water quality and accordance to different land use pattern. Three districts were decided for each area including Kota Bharu, Kemumin and Beta while for Pasir Puteh areas are Semerak, Limbongan and Jeram. Ten sampling station were chosen for every district. The details about sampling location were stated as in Table 3.1 and Table 3.2.

Table 3.1: Coordinate of sampling station at Kota Bharu area

District	Station no	Coordinate
Kota Bharu	Station 1	N 06 ⁰ 08.551' E 02 14.342'
	Station 2	N 06 ⁰ 08.671' E 102 ⁰ 14.464'
	Station 3	N 06 ⁰ 08.671' E 102 ⁰ 14.453'
	Station 4	N 06 ⁰ 08.662' E 102 ⁰ 14.444'
	Station 5	N 06 ⁰ 08.681' E 102 ⁰ 14.445'
	Station 6	N 06 ⁰ 08.690' E 102 ⁰ 14.448'
	Station 7	N 06 ⁰ 08.588' E 102 ⁰ 14.371'
	Station 8	N 06 ⁰ 08.698' E 102 ⁰ 14.571'
	Station 9	N 06 ⁰ 08.342' E 102 ⁰ 14.271'
	Station 10	N 06 ⁰ 08.491' E 102 ⁰ 14.299'

Beta	Station 1	N 05 ⁰ 59.259' E 102 ⁰ 12.430'
	Station 2	N 05 ⁰ 59.252' E 102 ⁰ 12.431'
	Station 3	N 05 ⁰ 59.733' E 102 ⁰ 12.612'
	Station 4	N 05 ⁰ 59.732' E 102 ⁰ 12.608'
	Station 5	N 05 ⁰ 59.646' E 102 ⁰ 12.486'
	Station 6	N 05 ⁰ 59.688' E 102 ⁰ 12.572'
	Station 7	N 05 ⁰ 59.753' E 102 ⁰ 12.623'
	Station 8	N 05 ⁰ 49.811' E 102 ⁰ 12.349'
	Station 9	N 05 ⁰ 59.653' E 102 ⁰ 12.513'
	Station 10	N 05 ⁰ 59.649' E 102 ⁰ 12.543'
Kemumin	Station 1	N 06 ⁰ 08.460' E 102 ⁰ 17.634'
	Station 2	N 06 ⁰ 08.460' E 102 ⁰ 17.649'
	Station 3	N 06 ⁰ 08.460' E 102 ⁰ 17.334'
	Station 4	N 06 ⁰ 08.960' E 102 ⁰ 17.344'
	Station 5	N 06 ⁰ 08.956' E 102 ⁰ 17.348'
	Station 6	N 06 ⁰ 08.958' E 102 ⁰ 17.356'
	Station 7	N 06 ⁰ 08.998' E 102 ⁰ 17.334'
	Station 8	N 06 ⁰ 09.144' E 102 ⁰ 17.283'
	Station 9	N 06 ⁰ 09.160' E 102 ⁰ 17.234'
	Station 10	N 06 ⁰ 09.166' E 102 ⁰ 17.290'

Table 3.2: Coordinate of sampling station at Pasir Puteh area

District	Station no	Coordinate
Semerak	Station 1	N 05 ⁰ 50.940' E 102 ⁰ 28.715'
	Station 2	N 05 ⁰ 50.981' E 102 ⁰ 28.738'
	Station 3	N 05 ⁰ 50.611' E 102 ⁰ 28.011'
	Station 4	N 05 ⁰ 50.611' E 102 ⁰ 28.043'
	Station 5	N 05 ⁰ 50.550' E 102 ⁰ 28.012'
	Station 6	N 05 ⁰ 50.568' E 102 ⁰ 28.007'
	Station 7	N 05 ⁰ 50.580' E 102 ⁰ 28.020'
	Station 8	N 05 ⁰ 50.305' E 102 ⁰ 29.221'
	Station 9	N 05 ⁰ 50.311' E 102 ⁰ 29.230'
	Station 10	N 05 ⁰ 50.365' E 102 ⁰ 29.177'
Limbongan	Station 1	N 05 ⁰ 50.046' E 102 ⁰ 23.998'
	Station 2	N 05 ⁰ 50.041' E 102 ⁰ 23.998'
	Station 3	N 05 ⁰ 50.141' E 102 ⁰ 23.641'
	Station 4	N 05 ⁰ 50.170' E 102 ⁰ 22.679'
	Station 5	N 05 ⁰ 50.172' E 102 ⁰ 22.688'
	Station 6	N 05 ⁰ 50.027' E 102 ⁰ 22.688'
	Station 7	N 05 ⁰ 50.022' E 102 ⁰ 22.890'
	Station 8	N 05 ⁰ 50.031' E 102 ⁰ 22.882'
	Station 9	N 05 ⁰ 50.010' E 102 ⁰ 22.864'
	Station 10	N 05 ⁰ 50.058' E 102 ⁰ 22.939'

Jeram	Station 1	N 05 ⁰ 49.808' E 102 ⁰ 21.348'
	Station 2	N 05 ⁰ 49.623' E 102 ⁰ 21.393'
	Station 3	N 05 ⁰ 49.602' E 102 ⁰ 21.384'
	Station 4	N 05 ⁰ 49.646' E 102 ⁰ 21.203'
	Station 5	N 05 ⁰ 49.612' E 102 ⁰ 21.190'
	Station 6	N 05 ⁰ 49.412' E 102 ⁰ 21.195'
	Station 7	N 05 ⁰ 49.628' E 102 ⁰ 21.169'
	Station 8	N 05 ⁰ 49.501' E 102 ⁰ 20.963'
	Station 9	N 05 ⁰ 49.482' E 102 ⁰ 20.910'
	Station 10	N 05 ⁰ 49.219' E 102 ⁰ 20.526'

3.3 DATA COLLECTION

This research was carried out by analyzing primary data from well water sampling at Kota Bharu and Pasir Puteh area. The water sample was analyze according to six main parameters which are DO, BOD, COD, SS, NH₃-N and pH to determine the WQI value. Besides, several heavy metals also were measured during this study such as Cd, Fe, Mn and Pb.

Observation also was carried out at the surrounding area of well water sampling to identify the factor that will affect well water quality.

3.4 INSTRUMENTATION

The Multi-parameter YSI 556 was used to measure in-situ parameter including temperature (°C), pH, DO (mg/L). YSI 5000 Dissolved Oxygen Meter, HACH DRB 200, HACH DR/890 Colorimeter and Atomic Absorption Spectrophotometer (AAS) were used for ex-situ analysis to measure BOD₅, COD, SS, NH₃-N and heavy metal. Global Positioning System (GPS) also was used to determine the actual coordinates of sampling station and to reconfirm the location of stations during the subsequent sampling periods.

3.5 SAMPLING METHOD

Well water samples were collected 3 times for each sampling station. The samples were collected once a month starting from December, January and February. It consist two types of method which were in-situ measurement and ex-situ analysis. For in-situ measurements, it measure physical parameter of well water such as turbidity (NTU), DO (mg/L) and pH. While for ex-situ analysis, the sample of water was collected for further test other parameter such as SS, NH₃-N, BOD, COD and also heavy metal.

During the sampling, water samples were collected in polyethylene and BOD bottles sample after allowing the water for a while. The samples were acidified with nitric and sulphuric acid. The collected samples were placed into cool box before delivered to laboratory.

3.5.1 In-situ measurements

The water temperature (⁰C), DO (mg/L) and pH were measured in the field as in situ measurements with Multi-parameter probe YSI 556 MPS. Water samples were taken at each sampling location using a pale. The YSI 5563 Probe Module was connected to the YSI 556 MPS and immersed into the water samples. The physical parameters were measure and recorded.

3.5.3 Ex-situ analysis

Water samples were analyzed in the laboratory for further test to evaluate parameters of water quality and heavy metal such as BOD, COD, SS, NH₃-N, Fe, Cd, Mn and Pb.

3.5.3.1 Biochemical Oxygen Demand (BOD)

BOD for each water sample was measured using 5 days test. The initial dissolved oxygen of each sample bottle was measured before incubation. The bottles were incubated in an incubator at 20 °C ± 1°C for five days. After 5 days, the remaining dissolved oxygen (DO) concentration in each bottle was measured. The BOD₅ of each sample was calculated using the following formula.

$$\text{BOD}_5, \text{ mg/L} = \frac{(D_1 - D_2)}{P}$$

Where:

D₁ = initial DO of sample, mg/L

D₂ = final DO of sample, mg/L

P = fraction of sample

Fraction of sample = $\frac{\text{Volume of sample}}{\text{(Volume of sample bottle)}}$