Assessment of Physico-Chemicals and Microbiological Parameters of Groundwater Quality in Tumpat, Kelantan

By

Wan Muhammad Syawal Bin W Rasir

A report submitted in fulfillment of the requirements for the degree of

Bachelor of Applied Science (Sustainable Science) with Honours

FACULTY OF EARTH SCIENCE

UNIVERSITY MALAYSIA KELANTAN

2017

DECLARATION

I declare that this thesis entitled "Assessment of Physico-Chemicals and Microbiological Parameters of Groundwater Quality In Tumpat, Kelantan" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ____________________________

Name : ____________________________

Date : ____________________________

ACKNOWLEDGMENT

First of all, I would like to thank Allah for His Guidance through my life and research. I also would like to express my sincere appreciation a gratitude to my very nice supervisor Dr Nurul Syazana Bt Abd Halim for her never ending advice, supervision and constant patience through this project and also both Dr Norimi Rosaida Awang and Sir Syakir Bin Sulaiman for their contribution.

Furthermore, I want to express my thanks deepest gratitude to all lecturers and lab assistance that were involving and guidance me in completing this paper. I am fully appreciated the valuable time and effort that they have spent for my final year project. The most importance in this research was support from my mother, Shripah Noraini bt syed Jamaludin for her taking a big part in completing this thesis.

Last but not least, my thanks to my entire beloved and crazy friend, Syahirah Atiqah, Nur Afida, Nur Syazwani, Mohd Syafiq, Muhammad Yus, Nur Izzah, Muhammad Amir and Muhammad Haziq who had given me so much support in completing this research. Thank you.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

BOD	Biochemical Oxygen Demand
DO	Dissolved Oxygen
TDS	Total Dissolved Solid
EC	Electrical Conductivity
DOE	Department Of Environment
Kg	Kampung
Sg	Sungai
NWQS	National Water Quality Standard Malaysia
WHO	World Health Organization
WWAP	World Water Assessment Programed
GPS	Global Positioning System
N	North
S	South

LIST OF SYMBOLS

°C	Degree Celcius
m	Meter
L	Liter
ms	Meter seconds
%	Percentage
Cm	Centimeter
km	Kilometer
min	Minute

Assessment of Physico-Chemicals and Microbiological Parameters of Groundwater Quality in Tumpat, Kelantan

ABSTRACT

It is estimated that 75 % of people in Kelantan use groundwater for domestic purpose which has made Kelantan as the bigger groundwater operator in Malaysia. Even though groundwater is natural renewable resources that are suitable to be used for domestic purpose but the water quality may also deteriorate due to human activity such as agriculture, residential development and industrial activities. Thus this study aims to examine the physico-chemicals and microbiological of bore water at Kampung Kok Keli in Tumpat, Kelantan. The physical groundwater characteristic such as temperature, turbidity, total dissolved solids, salinity, pH readings and electrical conductivity were measured directly at the site just after the sample were collected using YSI multi-parameter. The BOD test and microbes were also conducted. Moreover, the water table of the study area was examined using resistivity method. Then the water quality results were compared with WHO water quality standard value and National Water Quality Standard (NWQS). According to results obtained from analysis of physico-chemicals test shows that the groundwater samples for five locations at Kampung Kok Keli meets the requirement standard water quality value from National Water Quality Standards (NWQS) Malaysia and follow the standard guide from WHO. The analysis of groundwater samples indicate that groundwater quality at Kampung Kok Keli is in good condition and follow the standard water quality value.

Penilaian Parameter Fizikal-Kimia dan Mikrobiologi Bagi Kualiti Air Bawah Tanah di Tumpat, Kelantan

ABSTRAK

Dianggarkan terdapat 75% penduduk di Kelantan menggunakan air bawah tanah sebagai alternatif untuk kegunaan harian dimana peratusan ini membawa kepada Kelantan sebagai pengguna air bawah tanah terbesar di Malaysia. Walaubagaimanapun, penggunaan air semula jadi juga boleh dicemari dengan aktiviti setempat seperti pertanian, penternakan dan pembagunan kawasan. Kajian ini menyasarkan untuk mengkaji parameter fizikal-kimia dan mikrobiologi terhadap kualiti air bawah tanah melalui lima boring yang berbeza lokasi di sekitar Kampung Kok Keli Tumpat, Kelantan. Ciri fizikal air bawah tanah yang diuji menggunakan YSI multi-parameter termasuklah pH, kekeruhan air, suhu, jumlah pepejal larut, salinity dan eletrik konduktivity. Ujian BOD dan mikrobiologi juga dijalankan. Selain itu, taburan air bawah tanah juga diukur menggunakan kaedah kerintangan tanah. Hasil analisis kemudian dibandingkan dengan nilai standard air WHO dan National Water Quality Standard (NWQS) Malaysia. Keputusan ujian keatas parameter fizikal-kimia dan micribiologi air bawah tanah menunjukkan kualiti air bawah tanah di Kampung Kok Keli Tumpat berada diparas yang baik dan mengikut piawaian standard NWQS dan WHO, Analisis data memperakui kualiti air bawah tanah di kawasan Tumpat adalah dalam keadaan baik dan mengikuti standard nilai kualiti air.

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Water is used daily by living organism. There are various types of water demand namely domestic (60%), industry (35%) and agriculture (5%) (Kamal *et al.*, 2015). In Malaysia, the main freshwater supply is from surface water sources such as river, lake and stream. On the other hand, the use of groundwater for domestic purposes is mainly confirmed to rural areas where there is no availability for piped water supply. In addition, the use of groundwater as alternative primary supply is widely increased in Kelantan and Perlis due to availability access on groundwater table depth.

Lately, issues related to water quality and degradation of quality of freshwater especially the surface water is commonly reported in this day. As the world concerns over water resources and the environment increase, the importance of considering groundwater as an alternative resource has become popular in the past years. For the state of Kelantan, groundwater has been utilized for water supply in many years.

It is estimated that 75 % of people in Kelantan use groundwater for domestic purpose which has made Kelantan as the bigger groundwater operator in Malaysia (Ismail, 2004). Research study has shown that an intergranular aquifer found in Kelantan offers the greater potential in maximizing the utilization of this precious resource (Ismail, 2004).

However, many human activities affect the interactions of groundwater and surface water which cause deterioration of water quality. For example, contaminated aquifers that discharge to streams and groundwater can result in long-term contamination of surface water; conversely, streams can be a major source of contamination to aquifers. Therefore, the main purpose of this research is to identify physico-chemical and biological parameters of the groundwater in Tumpat, Kelantan.

1.2 Problems statement

Public water supply is a major issue especially in the state of Kelantan. Presently, Air Kelantan Sdn Bhd is the only water provider in this state. Not only the water supply is not enough but the quality itself is also a major concern that needs to be addressed. As an alternative, many residents especially at Kampung Kok Keli in Tumpat Kelantan use groundwater as substitute sources for water supply. Even though groundwater is natural renewable resources that are suitable to be used for domestic purpose but the water quality may also deteriorate due to human activity such as agriculture (Kamal *et al.*, 2015). According to research conducted at Kota Bharu and Pengkalan Chepa, the concentration of Chloride recorded in the three years stood at a rather extreme value which is far beyond the 250 mg/l set by the Ministry of Health (Kamal *et al.*, 2015). Therefore, this research aims to determine the groundwater quality level at Kampung Kok Keli and the values obtained were compared with national standard for drinking water quality by the Standard Malaysia and guidelines for drinking water quality by World Health Organization (WHO).

1.3 Objective of Study

The research focuses on identifying physico-chemical and biological constituents in groundwater at Kampung Kok Keli in Tumpat, Kelantan. Therefore, the present study aims the following objectives:

a. To determine the physico-chemical and biological parameters of groundwater samples from five different bore holes at Kampong Kok Keli, Tumpat, Kelantan
b. To determine the groundwater table using electrical imaging surveys at Kampong Kok Keli Tumpat, Kelantan
c. To compare the groundwater quality results from Kampung Kok Keli with National Standard For Drinking Water Quality by the Ministry of Health Malaysia and guidelines for drinking water quality by World Health Organization (WHO).

1.4 Significant of study

Groundwater is valuable substance on earth especially when surface water is not enough or badly polluted. The use of groundwater is important especially to the residents of Kampung Kok Keli in Tumpat, Kelantan. Therefore, maintaining the quality of groundwater is needed to ensure the safety of consumers. This study was conducted to help in determining the quality of groundwater at Kampung Kok Keli and identify whether its follow the Standard Malaysia and World Health Organization.

CHAPTER 2

LITERATURE REVIEW

2.1 Freshwater

Most of water on earth occurs as saline water in the oceans and deep underground or is contained in polar ice caps and the permanent ice cover of the high mountain ranges (UNESCO, 2006). So, only 30 million km^3 of fresh water, that is only two (2) percent of all water, plays an active part in the hydrological cycle and in the maintenance of all life on the continents (UNESCO, 2006).

The availability and quality of water in many regions of the world are more and more threatened by overuse, misuse and pollution, and it is increasingly recognized that both are strongly influenced by human activities (Mullaney, 2004).

Humans and any other living things depend on water for life, health and survival. The World Health Organization (WHO, 1993) reports that about 80 percent of the world's people live in places where the only available water is unsafe (UNESCO, 2006). Water-related problems such as overuse, scarcity, pollution, floods and drought are an increasingly important challenge to sustainable development (WHO, 1993).

Forested act as water catchments area that supply most of all water used for domestic, agricultural and industrial needs (Calder *et al*., 1998). The availabilities of the quality of water are strongly influenced by many factors such as deforestation any development and agriculture thus depend on proper management of natural resources.

Land use and water demand increasing fast due to exponential growth of population, agricultural, industrial and tourism purposes since past decades (Shirazi *et al*, 2015).

It has become difficult in recent years to construct reservoirs for surface storage of water because of environmental concerns and because of the difficulty in locating suitable sites (McFarlarnd *et al*., 2001). Management of one component of the hydrologic system, such as a stream or an aquifer, commonly is only partly effective because each hydrologic component is in continuing interaction with other components (McFarlarnd *et al*., 2001).

New residential development in certain area requires good conditioning of nature supply. When development is taking place in rural areas that are outside public water-supply areas, residents in these areas rely on individual private wells or boreholes drilled in the fractured crystalline- bedrock aquifer for their water supply (Mullaney, 2004).

It is possible that water use in homes with private wells may differ from those with public water supplies. For instance, homeowners with wells may use less water indoors because of the lower water pressure that is sometimes associated with private domestic water systems, or may be more or less inclined to fill or top off swimming pools, to water lawns, or to use water for other landscaping purposes (Harter, 2003).

2.2 Groundwater

Groundwater define as water that occurs under the ground surface of soil surface and in the fractures of rock formations also called Lithologic formation and an usable quantity of water is yielded from a unit of rock called Aquifer (Pradhan *et al*., 1988). It is getting completely saturated with voids of rock at the depth of soil pore spaces or fractures and forms water table (Pradhan *et al*., 1988).

Groundwater can occur in two principal zones, the unsaturated zone and the saturated zone. In the unsaturated zone, the voids between grains of gravel, sand, silt, clay, and cracks within rocks contain both air and water. Although a considerable amount of water can be present in the unsaturated zone, this water cannot be pumped by wells because it is held too tightly by capillary forces (Harter, 2003).

On the other hand, the voids in the saturated zone are completely filled with water. Water in the saturated zone is referred to as ground water. The upper surface of the saturated zone is referred to as the water table. Below the water table, the water pressure is great enough to allow water to enter wells, thus permitting ground water to be withdrawn for use.

Groundwater quality are of major concern to researchers because of increasing demand for fresh water coupled with climate change effects and also the effluents of waste generated from urban population, industries and agricultural activities may pollute soil and groundwater (Shirazi *et al*., 2015).

2.2.1 Groundwater boreholes

Groundwater ecosystems remain poorly understood due to the inaccessibility beneath the subsurface of soil. Boreholes provide the suitable sampling method to reach into the aquifers, and are commonly used for investigating invertebrates and microorganisms (Soresen *et al*., 2013).

A study conducted to demonstrates a new method of investigating local habitats within groundwater ecosystems by combining a variety of hydrogeological and biological techniques with a new conceptual understanding of the origin of water and microbes in pumped samples. This study found that borehole water had more bacterial counts and a different chemistry compared to aquifer water (Soresen *et al*., 2013).

Increases in borehole diameter beyond the drilled diameter may be indicative of fractures (Soresen *et al*., 2013). The investigation showed that there are significant differences between the borehole and aquifer water, suggesting that the boreholes are sites of enhanced biogeochemical cycling, bacterial activity were all higher in the borehole than in the aquifer. There was also some evidence that the bacterial community structure differed between the borehole water and aquifer water (Soresen *et al*., 2013).

2.2.2 Groundwater table

The depth to the water table can be calculated by installing wells that penetrate the top of the saturated zone (aquifer) just far enough to hold water (Thomas *et al*., 1998).

The depth to the water table is highly variable and can range from zero, when it is at soil surface, to hundreds or even thousands of feet in some types of landscapes (Thomas *et al*., 1998). Usually, the depth to the water table is small near permanent bodies of surface water such as streams, lakes, and wetlands.

Groundwater table is can change seasonally or from year to year because groundwater recharge, which is the accretion of water to the upper surface of the saturated zone, is related to the wide variation in the quantity, distribution, and timing of precipitation (Thomas *et al*., 1998).

In addition, there are various practical uses of a water table map (pseudosection) such as estimating an approximate depth for a proposed well and approximate direction of groundwater flow at any location on the water table through calculating the soil resistivity. Lines drawn perpendicular to water table contours usually indicates the direction of groundwater flow along the upper surface of the groundwater system (Winter *et al*., 1998). The following Figures 2.1 shows the standard water table resistivity.

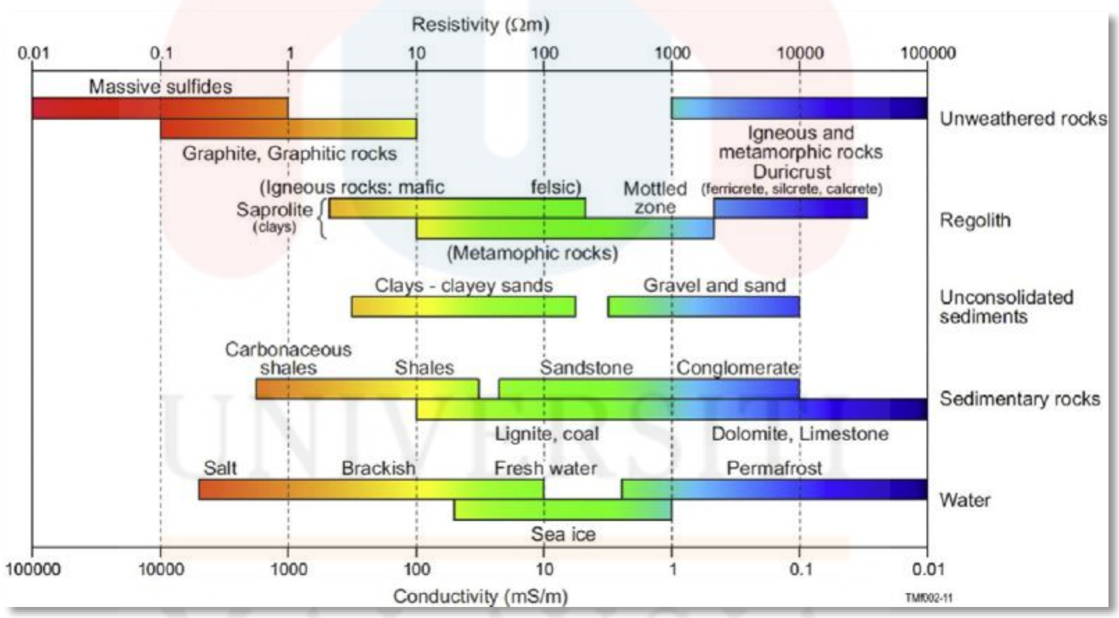

Figure 2.1: Range of resistivity values in the earth (Gonzalez *et al*., 2015).

Due to the water table is continually adjusting to changing recharge and discharge patterns, water level measurements must be made at approximately the same time, and the resulting map is representative only of that specific time (Thomas *et al*., 1998).

The water table technically defines as the imaginary surface in an unconfined aquifer at which the pressure is atmospheric (Moss, 1972). The water table is representing the top of the saturated zone, which all pores in the rock matrix are filled with water. The water table is defined by the levels at which water stands in wells that just penetrate the top of the water body (Moss, 1972).

Water quality parameter indicators include water temperature, dissolved oxygen, specific conductance, pH, alkalinity and turbidity. Water quality indicators are measured in the field and are sometimes also measured in the laboratory (pH and specific conductance) (Fetter, 1993).

Increasing water supply demand caused decreasing the water quality as a result of urban, industrial and agricultural activities on certain area. Therefore, it is necessary to preserve groundwater quality as one of components of water resources (Fianko *et al*., 2008).

Water quality parameter indicators provide basic information on the general quality of the water. Dissolved oxygen is the concentration of oxygen dissolved in the water and is an indicator of redox conditions in the aquifer. Measurements of pH indicate the acidity basicity of water. Specific conductance is a measure of how well the water conducts electricity and indicates the relative amount of dissolved solids in the water where turbidity is a measure of the suspended solids in the water (Fetter, 1993).

The quality of ground water in some parts of the country is changing as a result of human activities. Ground water is less susceptible to bacterial pollution than surface water because the soil and rocks through which ground water flows screen out most of the bacteria. Many unseen dissolved mineral and organic constituents are present in ground water in various concentrations. The quality of groundwater depends on the mineralogy, reactivity of drift materials and the degree of equilibrium that has been attained between water and rock, (Fetter, 1993).

2.3 Contamination of groundwater

Groundwater can become polluted from natural sources or variety types of human activities such as residential, municipal, commercial industry and agriculture activities. The occurrence of ground water contamination and the quality of ground water have become main issues since the discovery of numerous hazardous waste sites in the late seventies (Aller *et al.*, 1987). Groundwater pollution works differently from surface water pollution, although they have many sources in common, such as fertilizers, pesticides, and animal wastes (Harter, 2003).

2.3.1 Source of pollution

Based on the Figure 2.2, waste or dump site can be major contribution to groundwater pollution. Sources of ground water contamination are widespread as shown in Figure and include thousands of accidental spills, landfills, surface waste ponds, underground storage tanks, above ground tanks, pipelines, injection wells, land application of wastes and pesticides, septic tanks, radioactive waste disposal sites, salt water intrusion, and acid mine drainage.

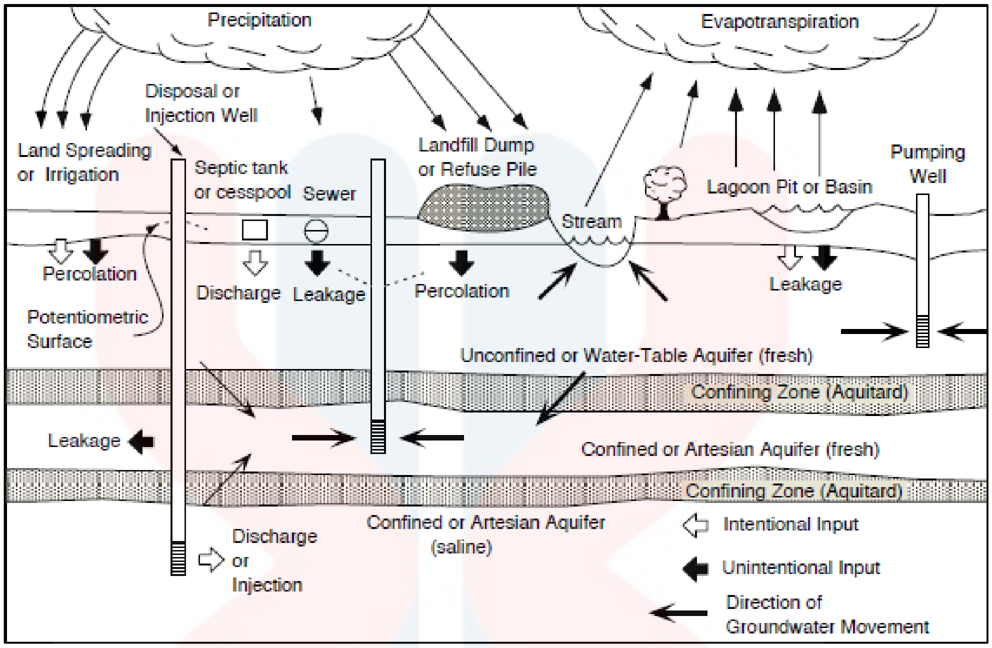

Figure 2.2: Waste disposal contaminate the groundwater system (US EPA, 1987)

2.3.2 Industrial and agriculture

The use of water for industrial sector are likely as cleaning, heating, cooling and generating steam, as a solvent and for transporting dissolved substances, and as a constituent part of the industrial product itself. Withdrawal of water for industry is usually much greater than the amount actually consumed (WWAP, 2006).

According to World Water Assessment Programmed (WWAP, 2006) also some of the wastes from industrial activities are direct disposal into the ground, or via streams, rivers and canals to aquifer. Besides that, the wastes are disposal to municipal sewer systems, which may or may not include sewage treatment and also treatment of wastewater on-site before disposal.

In assessing industrial impacts, the groundwater quality issues are likely to be much more dominant than quantity due to the volume of waste effluents and the concentrations of hazardous substances that industrial produced, combined with the mode of disposal and the vulnerability of the underlying groundwater which determine the risk of pollution (Morris *et al*., 2003).

Scientists have been examining the link between groundwater quality and particular increased of pesticides and fertilizers in agricultural practices (Candela *et al*., 1998). A study of frequency of various contamination sources considered to me main threats in United States shows nitrates from fertilizers are the most frequent factors in causing the groundwater contamination followed by pesticides (Fetter, 1993).

In addition, rural water supplies in many of the developing countries area are rarely treated and not normally monitoring despite the fact that research has shown that intensive agriculture can have a significant impact to groundwater quality, particularly as a result of the leaching of excess fertilizer derived nitrate from soils (Candela *et al*., 1998).

2.3.3 Groundwater contamination in Kelantan

Contamination of ground water can give bad impact to consumers such as result in poor drinking water quality, loss of water supply, degraded surface water systems, high cleanup costs, high costs for alternative water supplies and potential health problems.

Some agricultural practice can cause important pollution in aquifers due to the presence of nutrients or pesticides and increase in water salinity in arid regions which are area with less development, good drainage system and sandy soil texture. Season crop planting in Bachok and production of coconuts in Pengkalan Chepa and Sabak areas suing chemicals fertilizers would cause a surface water and groundwater contaminated (Kamal *et al*., 2015).

According to research conducted at Kota Bharu and Pengkalan Chepa, the concentration of Chloride recorded in the three years of the research period stood at a rather extreme value which is far beyond the 250 mg/l set by the Ministry of Health (Kamal *et al*., 2015). Presence of E.coli was found in groundwater at Pasir Puteh district that has been contaminated with the human waste in nature (Ismail, 2004).

2.4 Physico-chemicals parameter for water quality

2.4.1 pH

pH is define as the negative logarithm of the hydrogen ion concentration of a solution and it is thus a measure of whether the liquid is acid or alkaline (EPA, 1992). The pH scale is derived from the ionization constant of water are ranges from 0 (very acid) to 14 (very alkaline). The range of natural pH in fresh waters extends from around 4.5, for acid, peaty upland waters, to over 10.0 in waters where there is intense photosynthetic activity by algae. However, the most frequently encountered range is 6.5-8.0 (EPA, 1992).

pH is most important in determining the corrosive nature of water. Lower the pH value higher is the corrosive nature of water. pH was positively correlated with electrical conductance and total alkalinity (Guptaa, 2009).

2.4.2 Turbidity

Turbidity in water arises from the presence of very finely divided solids (which are not filterable by routine methods). The presence of turbidity in water will affect its acceptability to consumers and it will also affect markedly its utility in certain industries. It can be caused by sewage matter in water there is a risk that pathogenic organisms could be shielded by the turbidity particles and hence escape the action of the disinfectant (EPA, 1992).

Turbidity is important because it affects both the acceptability of water to consumers, and the selection and efficiency of treatment processes, particularly the efficiency of disinfection with chlorine since it exerts a chlorine demand and protects microorganisms and may also stimulate the growth of bacteria (WHO, 1993). In all processes in which disinfection is used, the turbidity must always be low preferably below 1 NTU.

2.4.3 Temperature

Water temperature is defined as the absence of thermal discharges generally climatologically influenced and the effect of temperature, and especially changes in temperature, on living organisms can be critical and the subject is a very wide and complex one (EPA, 1992).

In an established system the water temperature controls the rate of all chemical reactions, and affects fish growth, reproduction and immunity (Patil *et al*., 2012).

2.4.4 Electrical Conductivity

Conductivity shows significant correlation with ten parameters such as temperature, pH value, alkalinity, total hardness, calcium, total solids, total dissolved solids, chemical oxygen demand, chloride and iron concentration of water (Patil *et al*., 2012).

It was suggested that groundwater drinking water quality of study area can be checked effectively by controlling conductivity of water and this may also be applied to water quality management of other study areas (Navneet *et al*., 2010).

Electrical conductivity in water is an expression of its ability to conduct an electric current. As this property is related to the ionic content of the sample which is in turn a function of the dissolved (ionisable) solids concentration (EPA, 1992).

2.4.5 Dissolved Oxygen

DO is one of the most important parameter. Its correlation with water body gives direct and indirect information e.g. bacterial activity, photosynthesis, availability of nutrients, stratification etc. (Premlata, 2009). In the progress of summer, dissolved oxygen decreased due to increase in temperature and also due to increased microbial activity (Moss, 1972).

Dissolved oxygen (DO) formed when organic matter is discharged into a watercourse it serves as a food source for the bacteria present there. These will sooner or later commence the breakdown of this matter to less complex organic substances and ultimately to simple compounds such as carbon dioxide and water. If previously unpolluted, the receiving water will be saturated with dissolved oxygen (EPA, 1992).

2.4.6 Total Dissolved Solid

Total dissolved solid determine as the parameter comprises the total solids present in the whole sample which is analysed directly without filtration (EPA, 1992). In a water quality context the particles of greatest concern are the fine clays and silts.

Sediment in the water column is usually referred to as suspended sediment, and measured as a concentration in mg/l. Total dissolved solids indicate the salinity behavior of groundwater. Water containing more than 500 mg/l of TDS is not considered desirable for drinking water supplies, but in unavoidable cases 1500 mg/l is also allowed (Shrinivasa and Venkateswaralu, 2000).

2.4.7 Salinity

Salinity is defined as the measure of all the salts dissolved in water. Salinity is usually measured in parts per thousand (ppt). The average ocean salinity is 35 ppt and the average river water salinity is 0.5 ppt or less (EPA, 1992). Soil and water are classed as saline when these salts become present in quantities sufficient to adversely affect the growth and productivity of plants and animals (Patil *et al*., 2012).

The salts present in soils can be easily mobilized and transported by the movement of groundwater, capillary rise and evaporation, and leaching and biological activity. Ultimately, this may lead to the accumulation or depletion of salts in different parts of the landscape (Moss, 1972).

2.4.8 Biochemical Oxygen Demand

Biochemical Oxygen Demand (BOD) is one of important indicator parameter to identify the presence of biodegradable matter in waste and express degree of contamination (Deshmuk and Karanth, 1973). BOD is the amount of oxygen required by bacteria, while stabilizing decomposable organic matter under aerobic conditions (Delzer and McKenzie, 2003). The decomposable of organic matter and metabolic activities of bacteria results in utilization of a part of the dissolved oxygen (Chattopadhyaya *et al*., 1984). This depletion of oxygen is considered as a measure of the amount of degradable organic matter in the sample under analysis

The test for biochemical oxygen demand (BOD) is a bioassay procedure that measures the oxygen consumed by bacteria from the decomposition of organic matter (Bhalla *et al*, 2010). The change in DO concentration is measured over a given period of time in water samples at a specified temperature. The standard oxidation test period for BOD is 5 days at 20 degrees Celsius (°C) (Delzer and McKenzie, 2003). Standard calculation for BOD is determined using equation:

$$BOD = \frac{(Initial\ DO - Final\ DO)}{volume\ of\ BOD\ bottles} \qquad \text{Equation 2.1}$$

CHAPTER 3

MATERIALS AND METHOD

3.1 Study Area

The study area was located at Kampung Kok Keli in Tumpat, Kelantan. It is located at 6°10’0”N and 102°13’0”E and about 5 km North East from Tumpat town. The study area is about 0.5 km x 0.5 km cubic in size and nearby a river called Mak Neralang River. Most of locals in Kampung Kok Keli used groundwater as main water supply either by bore hole or open well. In this study, five bore holes from different houses within 200 m^2 of the area were chosen as sampling location. The locations were marked using GPS at the bore holes point. The houses was marked as Location A, B, C, D and E and the coordinate for each locations was determined by Global Positioning System (GPS) as shown in Figure 3.1 and Table 3.1. A water table of the study area was also measured and its GPS location is shown in Table 3.2.

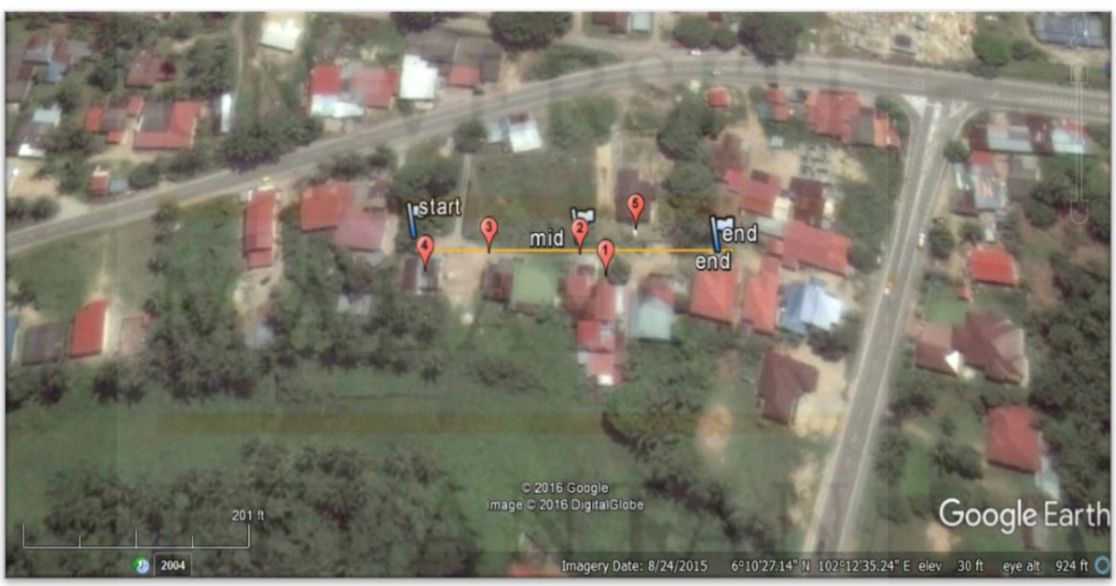

Figure 3.1: Geological map for boring water at Kampung Kok Keli.

Table 3.1: GPS location of boring water at Kampung Kok Keli.

Point name	GPS Coordinate	
	latitude	**Longitude**
Location 1	6°10'26.40"N	102°12'35.65"E
Location 2	6°10'26.62"N	102°12'35.39"E
Location 3	6°10'26.62"N	102°12'34.46"E
Location 4	6°10'26.44"N	102°12'33.81"E
Location 5	6°10'26.88"N	102°12'35.97"E

Table 3.2: GPS location of water table at Kampung Kok Keli.

Point name	GPS Coordinate	
	latitude	**Longitude**
Starting line	6°10'26.76"N	102°12'33.72"E
Middle line	6°10'26.71"N	102°12'35.42"E
Ending line	6°10'26.63"N	102°12'36.85"E

3.2 Materials and Methods

In this experiment, total of five water samples were collected from five different wells at Kampung Kok Keli in Tumpat, Kelantan. All the samples were collected in sterilized bottles and were stored at 4 °C within 24 hours. The analysis of water- quality parameters was carried out as per standard methods of WHO. Table 3.3 shows the list of apparatus and reagents that were used in this study.

Table 3.3: List of apparatus and chemicals

List of apparatus	List of reagents
ABEM Terrameter LS resistivity imaging system	Nutrient agar
YSI 556 MPS multi-parameter	Immersed oils
Glass bottle	Grams iodine
GPS	Crystal violet
Hammer	Safranin
Measuring tape	Distilled water
Ice box	Alcohol solution
Sterile vessels	
Petri dish	
BOD bottles	

3.3 Groundwater sampling and monitoring

3.3.1 Sampling and preservation

Before sampling, the icebox was completely filled with ice. All the bottles samples were labelled with stations/location name, date & time. For *E.coli* and total coliform sample, sterilized vessels without sodium thiosulfate were used to collect the water sample. While the dark glass bottle samples were used for BOD tests.

As for the precaution step, all the pipes connected to the bore holes were cleared and flamed to avoid any microorganism or bacteria infect the sampling water. Then, the pipes were open for water flow for several minutes before the sample water is collected to ensure the water sample collected is directly from underground. Lastly, sample water were capped and stored in ice box until they reach laboratory for analysis of BOD, *E.coli* and total coliform.

3.3.2 In situ water quality measurement

At each of the monitoring stations, temperature, pH, turbidity, salinity, total dissolved solid, DO and electrical conductivity were measured using YSI 556 MPS multi-parameter. A distill water was used to clean the probe prior to measurement. These tests were conducted along with the sampling process where the water was collected in the bucket for testing purpose. YSI sensor meter that has been stabilized were placed into the bucket containing groundwater sample for at least 10 minutes. Then, all the data were collected.

3.4 BOD test

BOD five day test for the five (5) stations were conducted at the lab Alam Sekitar UMK Jeli. First, 10 mL of groundwater sample was placed into a BOD bottles. Buffer solutions were added into the BOD bottles with no air bubbles in it. After that, initial DO concentration D_1 of each sample were measured carefully by inserting self-stirring sensor into the BOD bottles. Air entrapments were avoided and the sensor was left for one to two minutes allow the DO and temperature to stabilize at 20 ± 1 °C.

The stirred turned off and the sensor rinsed with distilled water/ deionized water. Glass stopper placed immediately to avoid air bubbles left in it. The BOD bottles were sealed with aluminum foil and the stopper overcaped on the BOD bottle to minimize evaporation. The BOD samples were placed in the air incubator at 20°C ± 1°C for five days. After five days, the BOD bottles removed from the incubator and the final DO concentration (D_2) were measured. The BOD_5 value for the five stations is then calculated using equation:

$$\text{Use } BOD_5 \text{ (mg/L)} = \frac{D1 - D2}{p} \qquad \text{Equation 3.1}$$

Where:

D_1: initial sample dissolved-oxygen (DO) concentration (in mg/L)

D_2: sample DO (in mg/L) after 5 days

P: decimal volumetric fraction of sample used

3.5 *E.coli* and total coliform test

Step 1: Dilution sample

Groundwater samples collected before also used for E.coli and total coliform bacteria test. First, the groundwater sample were placed in a sterile, transparent, no fluorescing vessel. 1 mL of samples were added to 9 mL of sterile diluent and mixed (dilution 1). Dilution 1 has a cell concentration 1/10 mL of the original samples. Each of 1 mL dilution 1 contains 1/10 mL from original sample. Then, 1 mL of dilution 1 added to another sterile diluent and form dilution 2. Step repeated until a series of three (3) dilution of original sample formed.

Step 2: Plating the dilution series

1 mL of dilution 1 was pipetted on nutrient agar plate using 1000 mL micropipette and then spread evenly using sterile glass rod. The step was repeated for dilution 2 and 3.

Step 3: Incubate the plates

The agar plates that have been sealed were incubated in incubator with 30 °C and for 24 hours. During incubation, each viable cell that was spread to a discrete position on the agar surface grew and divided many times to form a visible microorganism. Thus incubating the plates enables you to estimate the number of cell that present in the 1 mL of the sample.

Step 4: Counting the colonies

Colonies were counted through observation the agar plates after 24 hours incubation in incubator. Data counted and recorded.

Step 5: Determining the amount of viable organism

According to data from step 4, the amount of observed microorganism were multiple with three (3) as the dilution factor.

$$Number\ of\ microoganism\ per\ 1\ ml$$

$$CFU = number\ of\ colonies\ observed \times \text{ dilution factor} \qquad \text{Equation 3.2}$$

Step 6: Gram staining

I. Prepared a slide smear

With a sterile cooled loop, a drop of distilled water or alcohol solution placed on the slide. The loop sterilized and cooled again. Then, small colonies on agar plate picked up using that loop. The loop gently stirred into the drop of distilled water on slide to create emulsion.

II. Gram staining

A drop of crystal violet stain added over the dry culture and waited for 30 seconds. Then, crystal violets stain rinsed gently using distilled water and a drop of grams iodine added over the culture. Then gram iodine poured off and rinsed gently using distilled water. After that, dropped gently safranin to counter-stain and waited for 45 seconds. The slide tilted slightly and gently rinsed with distilled water. The slide dried with bibulous paper. Microorganism observed by viewed slide smear using a light-microscope under oil-immersion.

2.7 Electrical Resistivity

Electrical resistivity methods were used to investigate the depth to water table of the study area. In this experiment, a vertical area with minimum 100 meter length was used for determination of groundwater table using a two-dimensional (2-D) model, ABEM Terrameter LS resistivity imaging system. In this fieldwork, a multi-core cable attach with 42 electrodes connected by jointer cable with constant distance for 100 meter distance. A resistivity meter will be in the middle of 42 electrodes. The sequence of this measurement for the Wenner electrode array for a system with 21 electrodes and its spacing between adjacent electrodes is 2.5 m. The resistivity meter calculated and processed the water table after the arrangement of electrodes was completed and method chooses is Wenner array. Water table completed processed after 45 min and the data were transfer to computer for further analysis

Chapter 4

Results & Discussion

4.1 Physical & Chemicals parameters

Temperature, turbidity, salinity, pH, total dissolved solids (TDS), Dissolved Oxygen (DO) and Electrical Conductivity (EC) of the groundwater samples from five locations in Tumpat were evaluated using YSI 556 MPS multi-parameter. The findings were discussed below:

4.1.1 Temperature

The results of temperature for the five locations in Kampung Kok Keli are shown in Figure 4.1. Based on the figure, temperature for groundwater for the five location were between 29.87 to 32.14 °C. According National Water Quality Standard Malaysia there is no exact standard value for class I water supply temperature. When water temperature becomes too high, aquatic life suffer a variety of ill effects, ranging from decreased spawning success, to increase susceptibility to disease and toxins, to death (Patil *et al*., 2012). Water temperature also reduces the solubility of oxygen on which aquatic life depends and increases the toxicity of ammonia.

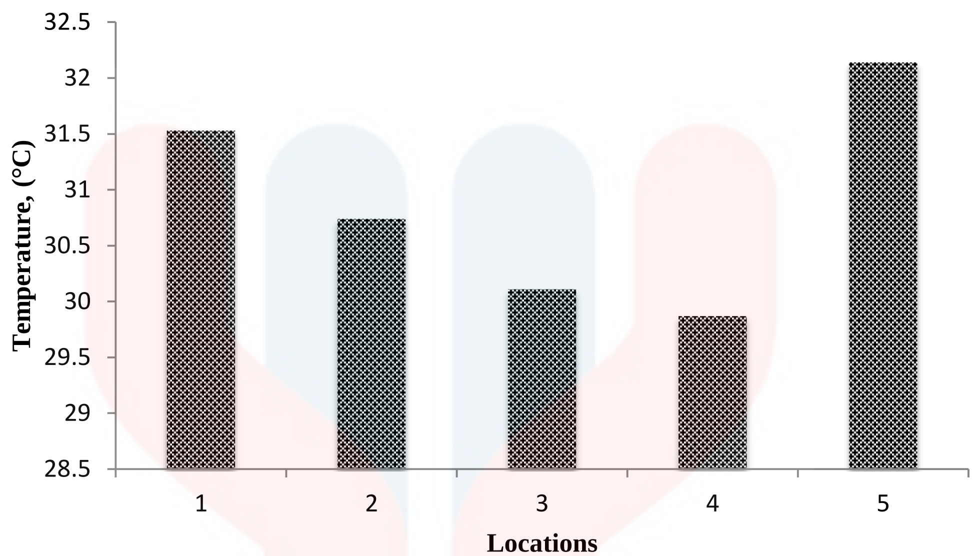

Figure 4.1: Groundwater temperature for five locations at Kampung Kok Keli

4.1.2 Turbidity

Turbidity is a measure of the clarity of the water and its unit is Nephelometric turbidity units (NTU). The turbidity results are shown in Figure 4.2. Based on the figure, location 2 has the highest turbidity which is 0.68 NTU where location 5 has lowest turbidity which is 0.24 NTU. According to National Water Quality Standard (NWQS) Malaysia, the recommended turbidity for raw water quality is 1000 NTU and for drinking water is 5 NTU. Therefore, the turbidity of groundwater at five (5) locations in Kampung Kok Keli is mostly lowers than 1 NTU is good condition for daily use. Lower value of turbidity measured parallel with lower value of dissolved solid in groundwater sample.

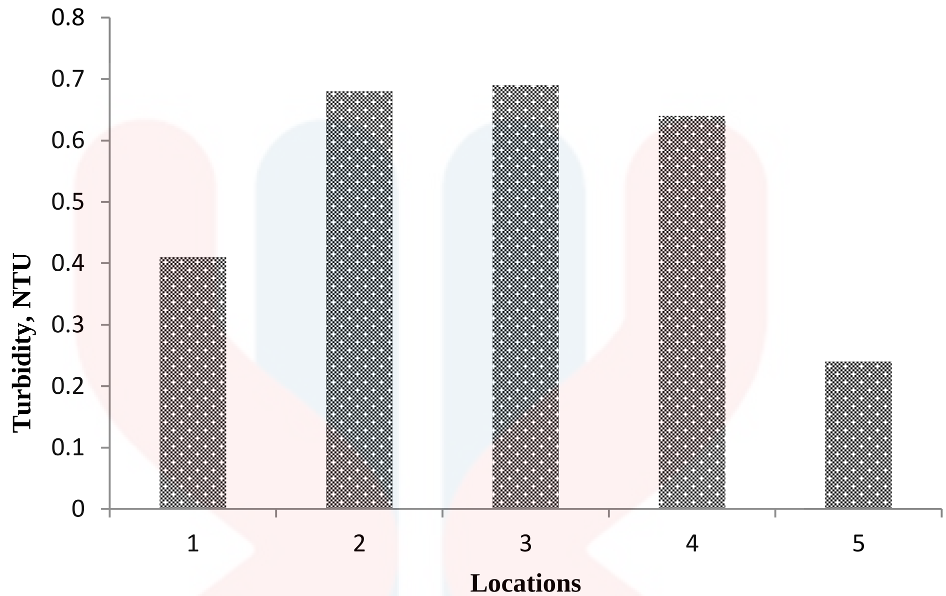

Figure 4.2: Groundwater turbidity for five locations at Kampung Kok Keli

4.1.3 pH

Figure 4.3 shows the results of pH readings at five locations in Kampung Kok Keli. The average pH of groundwater samples is 5.5 pH which near to pH 7. According to National Water Quality Standard (NWQS) Malaysia, it is recommended that pH 5.5-9.0 for raw water and 6.5-9.0 pH for drinking water. Therefore, the pH measured at Kampung Kok Keli is defined as good condition. In this study, there are many factors that can affect pH in water, both natural and man-made. Most natural changes occur due to interactions with surrounding rock (particularly carbonate forms) and other materials underground and for human made is the use of chemicals fertilizers in agriculture activities.

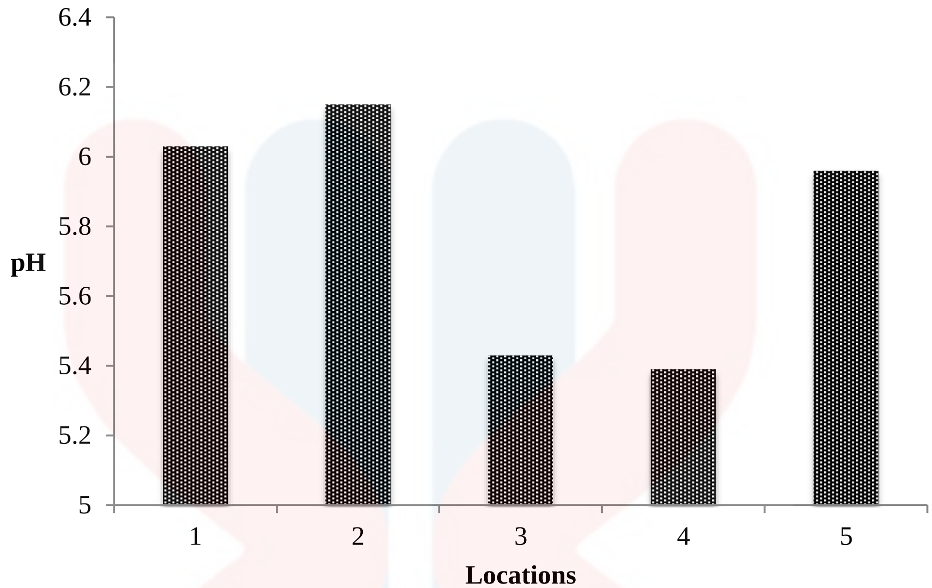

Figure 4.3: Groundwater pH for five locations at Kampung Kok Keli

4.1.4 Total dissolved solid, TDS

Total dissolved solids (TDS) combine the sum of all ion particles that are smaller than 2 microns (0.0002 cm). Figure 4.4 shows the results of TDS readings at five locations in Kampung Kok Keli. Based on the results, the highest TDS measured is Sample 2 which is 0.174 mg/L and lowest is Sample 3 which is 0.081 g/L. According to National Water Quality Standard (NWQS) Malaysia, total dissolved solid that recommended for raw water is 1500 mg/L and for drinking water are 1000 mg /L. Therefore, the results measured that TDS of groundwater sample at Kampung Kok Keli is in optimum condition which a lot less of contaminated with micro particles.

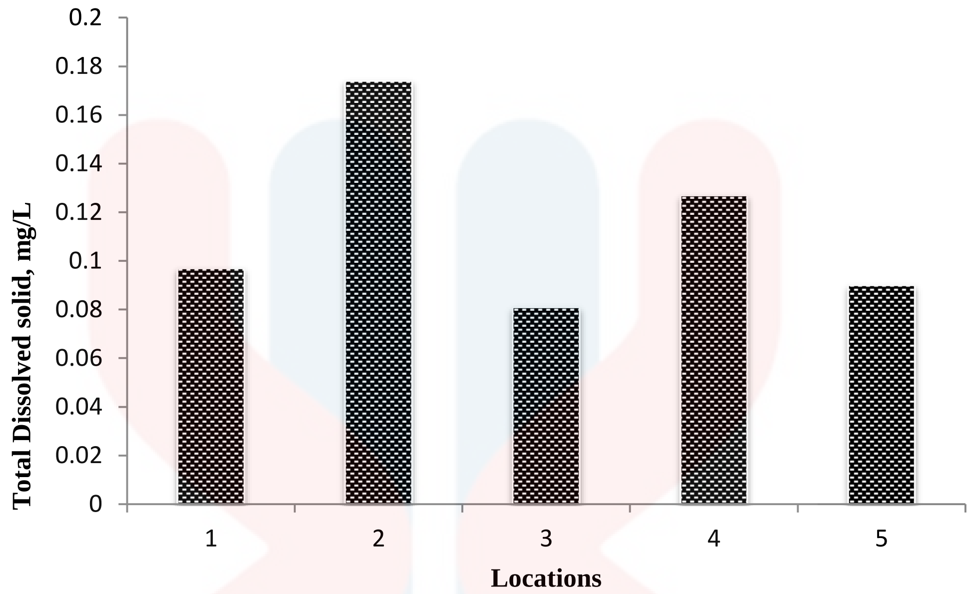

Figure 4.4: Groundwater TDS for five locations at Kampung Kok Keli

4.1.5 Salinity

Salinity is the total concentration of all dissolved salts in water. Salinity measurements based on conductivity values are unitless and known as practical salinity. Figure 4.5 shows the results of salinity readings at five locations in Kampung Kok Keli. According to results the location 2 has highest salinity which is 0.12 where location 3 & 5 has lowest salinity which is 0.06. The lower salinity causes less impact to environment. Salinity damage shortens the life of urban infrastructure such as roads, buildings and sewage pipes. This leads to costly maintenance and repair by homeowners.

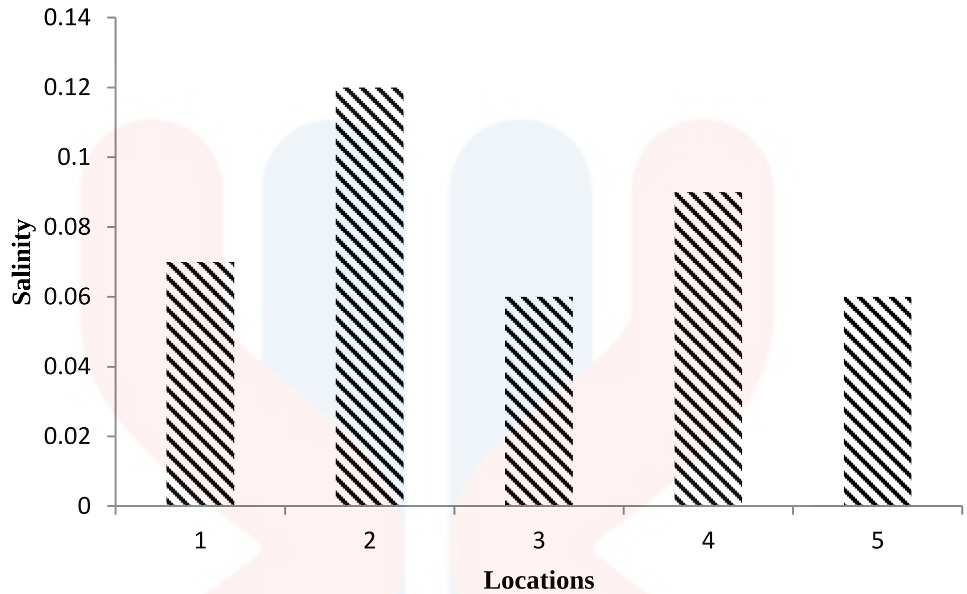

Figure 4.5: Groundwater salinity for five locations at Kampung Kok Keli

4.1.6 Dissolved Oxygen

The concentration of dissolved oxygen (DO) is a single, easy-to-measure characteristic of water that correlates with the health of aquatic life in a water body. Figure 4.6 shows results obtained from on-site test using YSI 556 MPS multiparameter and shows that highest percentage for DO readings is Sample 4 which is 4.16 mg/L and lowest is Sample 1 which is 0.83 mg/L. In this study, low DO is related to an excess of nutrients in water. Large quantities of nutrients in water can cause excessive growth of vegetation. This excessive vegetation, upon decay, can cause low DO. Other forms of organic matter, such as those present in sewage or food waste, can also lead to low DO.

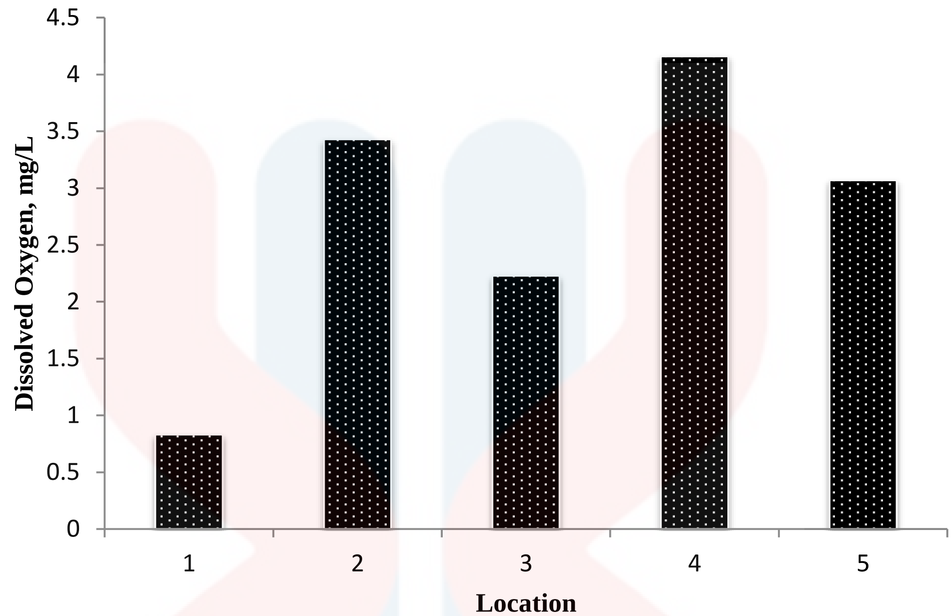

Figure 4.6: Groundwater dissolved oxygen for five locations at Kampung Kok Keli

4.1.7 Electrical Conductivity

Electrical conductivity (EC) is a measurement of the dissolved material in an aqueous solution, which relates to the ability of the material to conduct electrical current through it. EC is measured in units called Seimens per unit area (mS/cm, or miliSeimens per centimeter). Figure 4.7 shows the conductivity readings at five locations. Location 2 stated the highest conductivity which is 0.296 ms/cm where location 3 is the lowest with 0.136 ms/cm conductivity. Conductivity readings can determine as low dissolved material in groundwater samples at Kampung Kok Keli. The higher the dissolved material in water or soil sample, the higher the conductivity reading will get (Gonzalez *et al*., 2015).

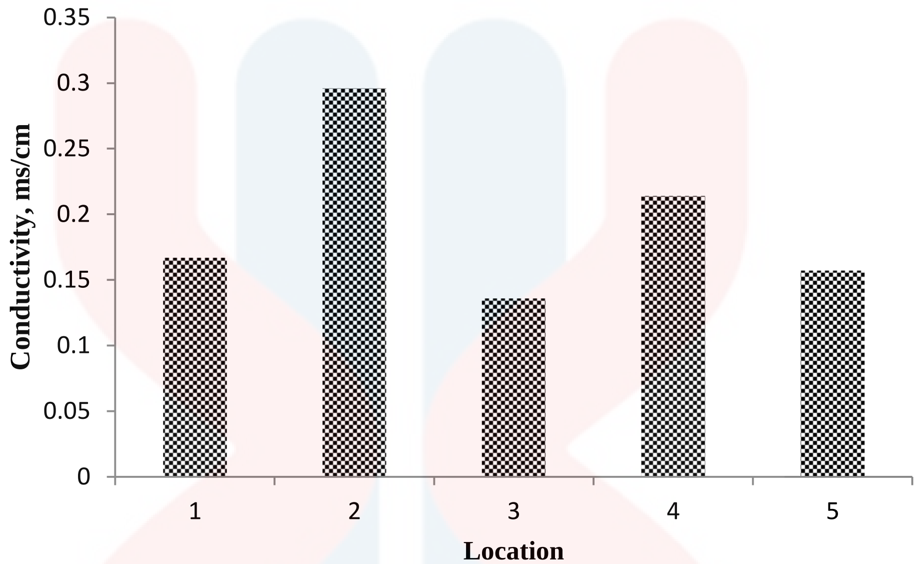

Figure 4.7: Groundwater conductivity for five locations at Kampung Kok Keli

4.1.8 Biochemical Oxygen Demand

Figure 4.8 shows the BOD results for five locations in Kampung Kok Keli, Tumpat Kelantan. The BOD reading was calculated after five days using equation (1). According to the Figure 4.8, the highest BOD reading is Sample 1 which is 0.93 mg/L and the lowest is Sample 3 which is 0.39 mg/L. BOD calculated shows that the readings is less than 1, thus we can assume that the condition of groundwater is good. The organic waste in groundwater sample is less so that fewer bacteria present to decompose that waste leading lower BOD readings.

According to National River Water Quality Standards, BOD readings for water supply class I require value less than 1 mg/L (WHO, 1993). We can determine the groundwater quality since Biochemical oxygen demand represents the amount of oxygen consumed by bacteria and other microorganisms while they decompose organic matter under aerobic conditions at a specified temperature. In this study, the lowest BOD determine the best condition of groundwater quality at Kampung Kok Keli where the highest BOD represent the worse groundwater quality that can be determine.

In this study, the readings of BOD can be influenced by the daily activities of local residents such as agriculture and animal husbandry. Residents of Kampung Kok Keli main activities are agriculture of paddy, animal husbandry of cow, sheep, duck and chicken. The plant growth and decay may be unnaturally accelerated by urban runoff that carries nutrients from lawn fertilizers; leaves, grass clippings, and paper from residential areas, which increase oxygen demand into groundwater (Kamal *et al*., 2015).

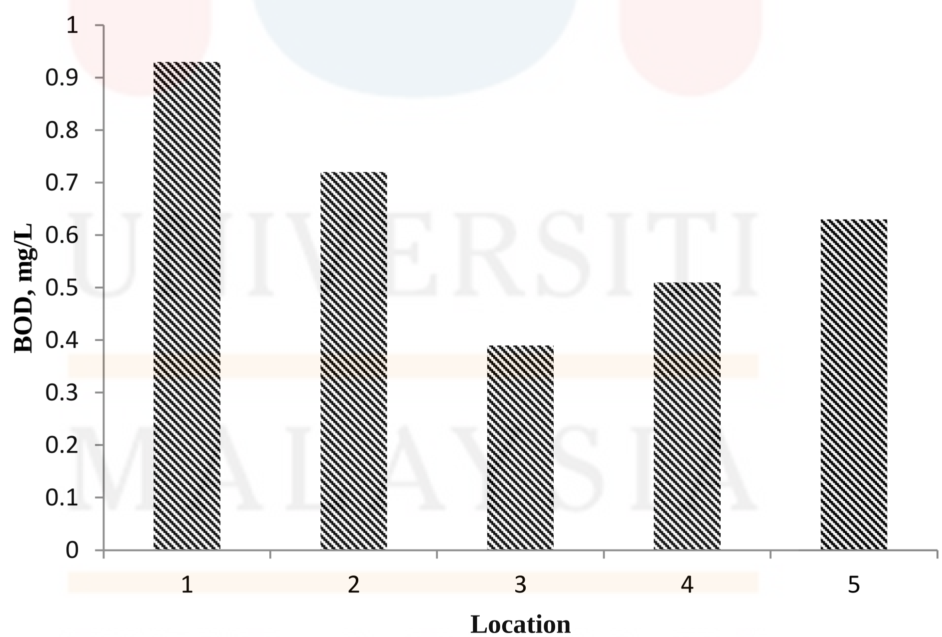

Figure 4.8: Groundwater BOD for five locations at Kampung Kok Keli

4.1.9 Summary

Table 4.1 shows the summary of all data parameters for physicals and chemicals test for five different locations at Kampung Kok Keli. According to the readings taken, we can determine the groundwater quality at Kampung Kok Keli is safe and good for natural water supply Class I. The values for each parameter are following the standard water quality value according to National River Water Quality Standards for Malaysia. The following table shows the basic parameters that used to test water quality in Kampung Kok Keli groundwater samples. Water quality testing is an important part of environmental monitoring. When water quality is poor, it affects not only aquatic life but the surrounding ecosystem as well. Therefore, it is important to identify this parameters to ensure it's safe for daily use.

Table 4.1: Physico-chemicals test parameters for five locations at Kampung Kok Keli

Location	Turbidity (NTU)	Temperature (°C)	pH	Total dissolved solid, TDS (g/L)	Salinity (%)	DO mg/L	EC (ms/cm)	BOD (mg/L)
1	0.41	31.53	6.03	0.097	0.07	0.83	0.167	0.93
2	0.68	30.74	6.15	0.174	0.12	3.43	0.296	072
3	0.69	30.11	5.43	0.081	0.06	2.23	0.136	0.39
4	0.64	29.87	5.39	0.127	0.09	4.16	0.214	0.51
5	0.24	32.14	5.96	0.090	0.06	3.07	0.157	0.63
WHO (2005)	5-7	Normal+2	6.5-8.5	<100	<0.5	4-7	500 (50ml/L)	<3
NWQS (DOE)	5	-	>7	<25	<0.5	>7	1000 (50ml/L)	<1

4.2 Microbial parameters

4.2.1 E.coli and Coliform test

Microbial test was conducted to test the present and absence of E.coli and total coliform in groundwater for five locations in Kampung Kok Keli, Tumpat Kelantan. Figure 4.10 and Figure 4.11 shows the observation of bacteria for present of *Escheria Coli sp* & total coliform under microscope.

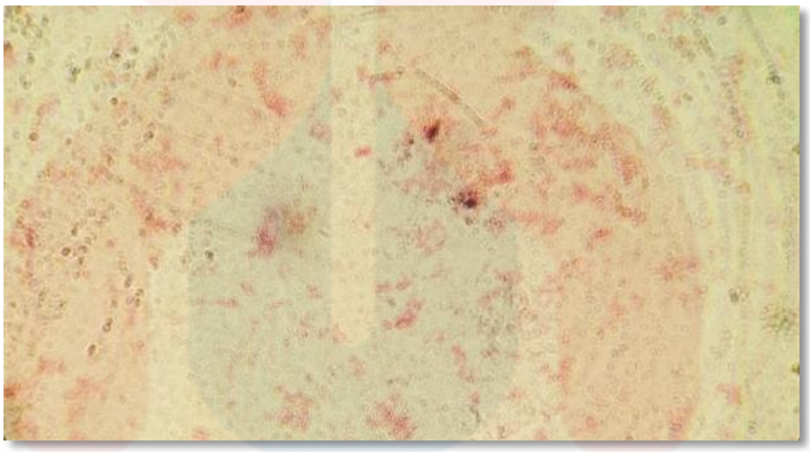

Figure 4.10 Observation under microscope 100x

Figure 4.11 Observation under microscope 100x

The following Table 4.2 shows the appearance of microbial through observations of agar plate of groundwater samples after 24 hours. The results show that location 4 has highest numbers of E.coli which is 15 per 1 ml samples where location 1 has 0 per 1 ml of groundwater samples. Based on the results, the amount of bacteria for five locations at Kampung Kok Keli meets the requirement for class I standard value according to National Water Quality Standards (NWQS) for Malaysia.

The small amounts of bacteria E.coli & coliform in groundwater can be relate with main activities and study area location. The primary activities for Kampung Kok Keli are agriculture and fisheries. Thus the sources for E.coli are limited which can reduce the contamination to water supply.

Table 4.2: Result observation per 1 ml after 24 hours incubation

Location	**CFU/ 1 ml**	
	E.coli	**coliform**
1	0	<100
2	3	>100
3	5	>100
4	9	>100
5	4	>100
NWQS Malaysia **(**CFU / 100 ml)	10	100
WHO 2005 **(**CFU/ 100 ml)	12	100

4.3 Electrical resistivity indicator

4.3.1 Pseudosection display for a Wenner array

Wenner array method used to determine the groundwater table at Kampung Kok Keli, Tumpat Kelantan. The following figures were generated using the Terrameter LS

Toolbox software package developed by ABEM Instrument AB. Figure 4.11 display the distribution of apparent resistivity of groundwater table at Kampung Kok Keli.

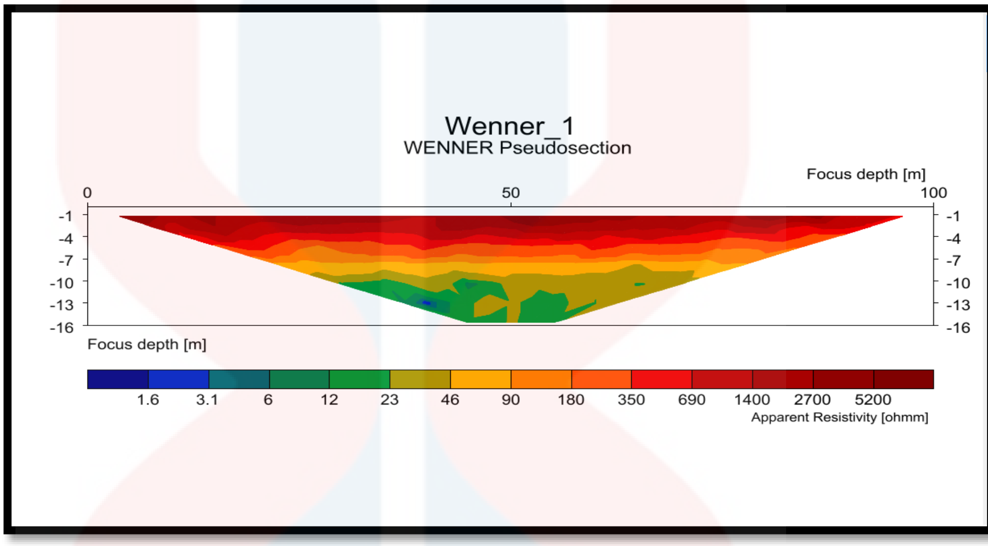

Figure 4.15: Selected resistevity of Kampung Kok Keli, Tumpat

Figure 4.15 show the upper layer is resistive (5200 Ωm) and the lower layer has a lower resistivity (1.6 Ωm). The maximum depth measured in this psedusection is sixteen (16) meter and maximum length is 100 meter. The following table shows how Wenner psedusection data been interpreted.

According to table above, Wenner pseudosection shows seven (7) m and below has 1-100 ohm which can be identifying as soil water. The pseudosection also shows the appearance of blue color on depth thirteen (13) m which described the present of groundwater. The upper layer has resistive 1000-10 000 which can be describe as gravel and sand.

According to local people, open well that located near to the sampling location has depth between seven (7) to thirteen (13) m. The depth of open well nearby is proper with the depth of groundwater table from pseudosection table.

Chapter 5

Conclusion and Recommendation

5.1 Conclusion

According to results obtained from analysis of physico-chemical test shows that the groundwater samples for five locations at Kampung Kok Keli meets the requirement standard water quality value from National Water Quality Standards (NWQS) Malaysia and follow the standard guide from WHO. The analysis of each quality test parameters test show that the condition of groundwater quality for daily purpose and groundwater quality at Kampung Kok Keli also can be classify as good and healthy for daily use.

In this study, the good results of groundwater quality test from five location can be relate with groundwater quality for another rural area which can be assume in good condition by analyzed the main activities on that area. It can be conclude that the use of groundwater as daily supply in Kelantan is safe for alternative and permanent water supply.

According to water table results, the depth of groundwater shows that it is reachable and possible to use as water supply. The maximum depth required for drilling a bore hole at Kampung Kok Keli is about 16 meter only. Shallow depth of water table can reduce the cost of drilling boring hole, thus can interest locals to use groundwater as daily water supply.

5.2 Recommendation

From this research, some recommendations are made in order to improve this research for better understanding of groundwater quality in Kelantan. Since objectives of this study only to determine the physico-chemicals and microbiological thus this study have limited amount of data and information that can be extracted from the groundwater quality. Therefore for further research, it is recommended that the chemicals parameters such as metals and organic content can be examined. This is because, the groundwater usually content calcium, magnesium, iron, aluminum and etc.

In the current research, only five locations were selected for groundwater sampling. So the results obtained from this study are limited and cannot represent Tumpat as a whole. Therefore, it is suggested that sampling location should be added more in order to get more reliable data information on the groundwater quality in Tumpat or any others study area.

Lastly, for the geological electrical resistivity, only the raw data was interpreted. This data only represent the resistivity pseudosection and it should be analyze further using specific software in order to extract more data about the groundwater aquifer such as soil structure, rocks or nutrient that contain beneath the water table. On the other hand, we can determine the type of watershed and groundwater such as deep or shallow groundwater based on the water contains inside the aquifers.

REFERENCES

Arnold, T. L., DeSimone, L. A., Bexfield, L. M., Lindsey, B. D., Barlow, B. R., Kulongoski, J. T.,Belitz, K. (2016). Groundwater-Quality Data from the National Water-Quality

Aller, L., T. Bennett, J. Lehr, R. J. Petty, G. and Hackett,1987.,DRASTIC: A standardized system for evaluating ground water pollution potential using hydrogeologic settings. U.S. EPA. EPA- 600/2-87-035.

Assessment Project, May 2012 through December 2013. *U.S. Geological Survey, Reston, Virginia, 997*.

Bhalla, G., Kumar, A. and Bansal, A. (2010): Assessment of Groundwater Pollution Near Municipal Solid Waste Landfill. *Asian Journal of Water, Environmental and Pollution.* 8(1): 41-51.

Candela. L., S. Rao., M. Margiotta., & Reboucas., A. (1998). Soil and Groundwater pollution from agricultural activities. *Innternational Hydrology programme, 5*(19).

Calder. I., T. Hofer., S. Vermont., & Warren., P. (2007). Forests and water. *An international journal of forestry and forest industries, 58*(0041-6436).

Chattopadhyaya.S. N,. R Sharma; VP Arora; and P K Gupta;1984,*Indian J. Environ, Health*.,26, 244-257

Delzer, G.C., and McKenzie, S.W., November 2003, Five-day biochemical oxygen demand: U.S. Geological Survey *Techniques of Water-Resources Investigations*, book 9.

Deshmukh, D.S. and Karanth, K.B.(1973) : Chemical quality rating in groundwater in south India. *Int. Symp.on Development of Groundwater Resources*., Madras 3: 1-8

Environment Protection Agency,1992, Parameters of Water Quality : Interpretation and Standards, published 2001.

Fetter. C.W., 1993 Contaminant Hydrogeology. *Macmillan Publishing*,London,3223-8.

Fianko. J. R., S. Osae., D. Adomako., & Achel., D. G. (2008). Relationship between land use and groundwater quality in six districts in the eastern region of Ghana. *Environ Monit Assess, 153*(139–146).

Gupta, D. P., Sunita and J. P. Saharan, (2009), Physiochemical Analysis of Ground Water of Selected Area of Kaithal City (Haryana) India, Researcher, 1(2), pp 1-5.

Gonzalez. A. I, A.Y Ley Cooper and W. Salama., Geological assessment of airborne electromagnetics for minerals exploration through deeply weathered profiles in the southest. Ore Geology reviews ,2015.

Harter, T. (2003). Groundwater Quality and Groundwater Pollution. *Nutrients and Water Quality*(8084).

Lin, X., ., Burns, R. C., ., & Lawrance, G. A., . (2005). Heavy Metals Inwastewater: The Effect Of Electrolyte Composition On The Precipitation Of Cadmium(Ii) Using Lime And Magnesia. *Water, Air, and Soil Pollution*, *165*, 131–152.

Morris, BL., Lawrence, AR., Chilton, PJ, Adams, B, Calow, R and Klinck, BA. 2003. Groundwater and its susceptibility to degradation: A global assessment of the problems and options for management. Early Warning and Assessment Report Series, RS, 03-3. United Nations Environment Programme, Nairobi, Kenya.

Moss, B., (1972), Studies on Gull Lake, Michigan II. Eutrophication Evidence And Prognosis, Fresh Water Biology, 2, Pp 309-320.

McFarland.M.L, & Dozier.M.C. (2001). Drinking Water Problems: Ironand Manganese. *The Texas A&M University System*.

Mullaney, J. R. (2004). Water Use, Ground-Water Recharge and Availability, and Quality of Water in the Greenwich Area, Fairfield County, Connecticut and Westchester County,

Ismail. M (2004). Kajian Kualiti Air Tanah Di Jajahan Pasir Puteh, Kelantan.Universiti Putera Malaysia.

Kamal.M.Z.A.M, Dr. Noorazuan Md. Hashim., Mohd Saupi Bin Mohd Zin,2015. Seawater Intrusion In The Ground Water Aquifer In The Kota Bharu District, Kelantan, *International Journal of Social Sciences*. Special Issue, 2015, pp. 320-327.

New York, 2000–2002. *Water-Resources Investigations Report, 03-4300*. P.N. Patil., D.V. Sawant., & Deshmukh., R. N. (2012). Physico-chemical parameters for testing of water – A review. *International Journal Of Environmental Sciences, 3*(0976 – 4402).

Navneet, Kumar, D. K. Sinha, (2010), Drinking water quality management through correlation studies among various physicochemical parameters: A case study, International Journal of Environmental Sciences, 1(2), pp 253-259.

National Water Quality Standards For Malaysia (NWQS), Department of Environment (DOE) Malaysia Water Environment Partnership in Asia (WEPA)

Pradhan, A.K., Mohapatra, S., Chand, S.K., Panda, A.P., Kumar, A., Sarangi, B., Qualitative Aspects of Groundwater in the Area of Regional Engineering College, National Seminar, Rourkela, India, Feb.,1988.

Pankow, JF and Cherry, JA. 1996. Dense chlorinated

Premlata. V, (2009), Multivariant analysis of drinking water quality parameters of lake Pichhola in Udaipur, India. *Biological Forum*, *Biological Forum- An International Journal*, 1(2), pp 97-102.

Shirazi.S.M, Md. Ibrahim Adham., Noorul Hassan Zardari., Zubaidah Ismail., Hosen MD Imran., & Mangrio., M. A. (2015). Groundwater Quality And Hydrogeological Characteristics Of Malacca State In Malaysia. *Journal Of Water And Land Development*, *11-19*, 1429–7426.

Sorensen, J. P. R., Maurice, L., Edwards, F. K., Lapworth, D. J., Daniel, S., Allen, D., Williams, P. J. (2013). Using Boreholes as Windows into Groundwater Ecosystems. *PLoS ONE*, *8*(7).

Shrinivasa.R.B. and Venkateswaralu P.,(2000),Environemntal Science.,*Indian J.Environ.Prot*.,20(3),361.

Winter.T.C,. J.W. Harvey., O. L. Franke., & Alley., W. M. (1998). Ground Water and Surface Water A Single Resource. *U.S. Geological Survey Circular 1139*(98–2686).

Thomas, G.H., Zarnescu, D.C., Juedes, A.E., Bales, M.A., Londergan, A., Korte, C.C., Kiehart, D.P. (1998). Drosophila Heavy-spectrin is essential for development and contributes to specific cell fates in the eye. Development 125(11): 2125--2134

WWAP. 2006. *Water:* A Shared Responsibility. *The United Nations World Water Development Report 2*. UNESCO, Paris and Berghahn Books, New York.

WHO, 1993,.Guidelines For Drinking-Water Quality, Second Edition, World Health Organisation, Geneva. 1993.

APPENDICES

Figure A1: Boring Water Engine

Figure A2: Boring Water Engine

Figure B1: ABEM Terrameter Resistivity Test

Figure B3: YSI Multi-parameter test