UNIVERSITI PUTRA MALAYSIA

A CROSS SECTIONAL STUDY ON NITRATE IN GROUNDWATER AND ITS HEALTH RISK ASSESSMENT AMONG RESIDENTS IN TUMPAT, KELANTAN

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A CROSS-SECTIONAL STUDY ON NITRATE IN GROUNDWATER AND ITS HEALTH RISK ASSESSMENT AMONG RESIDENTS IN TUMPAT, KELANTAN

BY

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ABSTRACT

A CROSS-SECTIONAL STUDY ON NITRATE IN GROUNDWATER AND ITS HEALTH RISK ASSESSMENT AMONG RESIDENTS IN TUMPAT, KELANTAN

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Introduction: Nitrogen in water can initiate from both natural and anthropogenic source that can reach surface water and groundwater. Nitrate can easily move through water and soil when there is excessive rainfall and excessive nitrate from agricultural fertilizer. When high amount of inorganic nitrogen is use as fertilizer in a rice cultivation, the fertilizer will be decomposed to an ammonia and it will be oxidized to nitrite and nitrate. Nitrogen from fertilizer will easily move to the groundwater and high concentration of nitrate in groundwater will affect the residents who use groundwater as their source of drinking water. **Objective**: The aim of this study is to determine the level of nitrate in groundwater and health risk assessment in Cherang Melintang Village at Tumpat, Kelantan located in north-east of Peninsular Malaysia. **Methodology**: A cross-sectional study was conducted in January 2020 to determine the association health risk and nitrate exposure in groundwater. Data collection for this study are using water sampling technique for water analysis and questionnaire to collect the data from respondents. Nitrate level were determined using Portable PH/ORP/ISE Meter Model HI98191 with an attached nitrate electrode. **Results**: The concentration of nitrate does not exceed the maximum acceptable nitrate level in drinking water that is 10mg/L. The Mean ± SD of the nitrate concentration was 2.91 ± 2.57 ppm, while the range was from 0.42 – 8.78 ppm. Besides, for characteristics of wells the Mean ± SD of age of wells, depth of wells and distance of wells from source of nitrate is 3.24 ± 1.779, 2.40 ± 0.782 and 14.04±8.425. **Discussion**: Based on the data that was collected during January 2020, the concentration of nitrate in the study area's groundwater was below the Malaysian National Drinking Water Quality Standard (NDWQS) Maximum Permissible Limit and the USEPA International Standard (10 mg L^{-1}). From the spearman rho correlation test, neither age (years) nor depth (meter) had no significant correlation with nitrate concentration is above 0.05 ($p > 0.05$). Indeed, there is a significant correlation between distance of well from source of nitrate (meter) and nitrate level ($p < 0.05$) with the coefficient of correlation, r = - 0.40. **Conclusion**: The residents in Cherang Melintang Village can still consume drinking water source from groundwater because the result obtained for Hazard Quotient (HQ) was lower than 1 which it is no adverse health impact on residents due to nitrate exposure

Keywords: Nitrate, Groundwater, Hazard Quotient, Kelantan

ABSTRAK

KAJIAN KERATAN RENTAS TERHADAP NITRAT DIDALAM AIR BAWAH TANAH DAN PENILAIAN RISIKO KESIHATAN DIKALANGAN PENDUDUK DI TUMPAT, KELANTAN.

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Pengenalan: Nitrat didalam air berpunca dari sumber semula jadi dan sumber buatan manusia yang boleh mempengaruhi air bawah tanah. Nitrat dapat meresap ke dalam air bawah tanah apabila terdapat penggunaan baja berlebihan daripada sektor pertanian dan apabila musim hujan. Apabila baja digunakan secara berlebihan didalam penanaman padi, baja tersebut akan terlerai membentuk ammonia. Nitrogen daripada baja akan memberi kesan kepada penduduk yang menggunakan air bawah tanah sebagai air minuman mereka. **Objektif:** Tujuan kajian ini adalah untuk mengetahui tahap nitrat didalam air bawah tanah dan risiko kesihatan di Kampung Cherang Melintang di Tumpat, Kelantan yang terletak di timur laut Semenanjung Malaysia. **Metodologi:** Kajian keratan rentas ini telah di jalankan pada bulan januari 2020 bertujuan untuk menilai hubungan antara risiko kesihatan terhadap pendedahan kepada nitrat di dalam air bawah tanah. Pengumpulan data untuk kajian ini dengan menggunakan teknik pengambilan sampel air untuk analisis dan soal selidik untuk mengumpulkan data daripada responden. Tahap nitrat ditentukan menggunakan Portable PH/ORP/ISE Meter Model HI98191 dengan elektrod nitrat yang dipasang. **Hasil Dapatan:** Kepekatan nitrat tidak melebihi tahap maksimum nitrat yang boleh ditetapkan dalam air minuman iaitu 10mg/L. Purata ± Sisihan Piawai kepekatan nitrat adalah 2.91 ± 2.57 ppm, sementara julatnya adalah dari 0.42 - 8.78 ppm. Selain itu, bagi ciri-ciri telaga, Purata ± Sisihan Piawai umur telaga, kedalaman telaga dan jarak telaga dari sumber nitrat adalah 3.24 ± 1.779, 2.40 ± 0.782 dan 14.04 ± 8.425. **Perbincangan:** Berdasarkan pengumpulan data yang dilakukan pada bulan januari 2020, kepekatan air bawah tanah di kawasan kajian didapati tidak melebihi Standard Kualiti Air Minuman Nasional (NDWQS). Dari ujian korelasi spearman rho, baik usia (tahun) maupun kedalaman (meter) tidak mempunyai korelasi yang signifikan dengan kepekatan nitrat melebihi 0.05 ($p > 0.05$). Tetapi, terdapat hubungan yang signifikan antara jarak telaga dari sumber nitrat (meter) dengan tahap nitrat ($p < 0.05$) dengan pekali korelasi, $r = -0.40$. **Kesimpulan:** Penduduk di Kampung Cherang Melintang masih boleh menggunakan sumber air minuman dari air bawah tanah kerana hasil yang diperolehi untuk kuantiti bahaya (HQ) lebih rendah daripada 1 iaitu tidak memberi kesan buruk kepada penduduk tempatan disebabkan pendedahan kepada nitrat.

Kata Kunci: Nitrat, Air Bawah Tanah, Kuantiti Bahaya, Kelantan

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HDPE	High Density Polyethylene
AKSB	Air Kelantan Sdn. Bhd.
NDWQS	National Drinking Water Quality Standard
HQ	Hazard Quotient
EEA	European Environment Agency
US EPA	United State Environmental Protection Agency
IARC	International Cancer Research Agency
MCL	Maximum Contaminant Level
MAV	Maximum Acceptable Value
MPL	Maximum Permissible Limit
WHO	World Health Organization
ADD	Average Daily Dose
NHEAS	National Human Exposure Assessment Survey
GPS	Global Positioning System
ISA	Ionic Strength Adjuster
IBM SPSS	Statistical Package for the Social Sciences

CHAPTER 1

INTRODUCTION

1.1 Background

Nitrate and Nitrate is occur in nature that become part of nitrogen cycle. Nitrate ion (NO_3^-) is the source of nitrogen used in the oxygenate system. (Guidelines & Quality, n.d.). Nitrogen in water can initiate from both natural and anthropogenic source that may enter surface water and groundwater. But, compared to the agricultural sector, natural sources contribute minimally to high water nitrate levels. Excessive use of nitrogen-based fertilizers, degradation of nitrogen waste products in human and animal excreta, including septic tanks is the source of nitrate which is from natural sources. (WHO Guidelines for Drinking-water Quality). Nitrate can easily move through water and soil when there is excessive rainfall and excessive nitrate from agricultural fertilizer. The concentration of nitrate in surface water is usually low (0–18 mg / l), but due to agricultural runoff, contamination of human or animal waste, it can reach high levels. Nitrogen is an important nutrient that is needed for agriculture. In contrast to fertilizers, nitrogen happens naturally in soil in organic forms from dying plant and animal residue. In soil, microorganisms convert various sources of nitrogen to nitrate, a nitrogen/oxygen ion(NO_3^-). This is necessary because the majority of nitrogen used by plants is consumed in nitrate form.

In agricultural sector which is rice cultivation, high level of inorganic nitrogen in water is essential substances for rice growth and production. (Ikeda & Watanabe, 2011). When high amount of inorganic nitrogen is use as fertilizer in a rice cultivation, the fertilizer will be decomposed to an ammonia and it will be oxidized to nitrite and nitrate. (Guidelines & Quality, n.d.). Nitrogen from fertilizer will easily move to the groundwater and high nitrate content in groundwater may impact people who have used groundwater as their drinking water source.

Residents who use well water (groundwater) as their drinking water sources will be higher probability to expose to higher level of nitrate because they use it without any treatment and monitoring. (Shamsuddin, Norkhadijah, Ismail, Abidin, & Bin, 2018)

The health problems related to excessive level of nitrate in drinking water to human health is methemoglobinemia among infant under 6 months and cancer in digestive tract of adults. (Guidelines & Quality, n.d.). Methemoglobinemia among infant is cause by ingesting high doses of nitrate by mistake or medical treatment. The two causes of severity of methemoglobinemia are age, race, genetics or other health condition, and new-borns under 6 months of age are prone to this syndrome. (Jaturong at al., 2015).

Health risk assessment and determination of nitrate concentration can be conducted to assess whether or not villagers have been exposed to the disease. Nitrate concentration can be determine by using water sample from each residents' house that are directly from well by using High Density Polyethylene (HDPE) bottle and replicated by two times. Then, the nitrate level in the water sample will be analyzed by using Portable PH/ORP/ISE Meter model HI98191 and Probe Model HI4113. The questionnaire will be given to the respondent to collect the information.

1.2 Problem Statement

The problem is when some of the resident at Tumpat, Kelantan did not get water supply from Air Kelantan Sdn. Bhd. (AKSB) because of the problems with water quality of surface water resource. (Shamsuddin et al., 2018). The quality of water supply in Kelantan was dirty and smelly because of frequent water disruptions and low coverage performance. (Association of Water and Energy, 2011). To overcome this problems, residents in Tumpat, Kelantan use private wells (groundwater) as their source of drinking water and for daily use. The using of private wells will increase the probability to expose with nitrate because they use it without treatment and monitoring. (Shamsuddin et al., 2018).

1.3 Study Justification

Residents in Kelantan use groundwater for drinking water since 1935. (Sheikhy, Zaharin, Se, & Keesstra, 2017). Tumpat is one of the district in Kelantan that still using groundwater (well water) as their daily water source. But , some of the resident in Tumpat get a water supply from sole provider that provide water services in Kelantan that is Air Kelantan Sdn Bhd (AKSB). This is because some place in Tumpat did not have enough piping system to get a water supply from AKSB. Furthermore, there is agricultural activities that using fertilizer that may affect the quality of groundwater in Cherang Melintang Village at Tumpat, Kelantan. There is paddy plantation that are surrounding Cherang Melintang Village that will affect the quality of water. In addition, land use in Tumpat district us mainly covered by the agricultural area that have a significant potential for nitrate contamination to the groundwater. (Shamsuddin et al., 2018)

1.4 Research Question

1) Is the concentration of nitrate in drinking water exceed maximum acceptable value by Drinking Water Quality Standard (DWQS).
2) Is the depth of well and distance of well from the paddy field area have an impact on groundwater nitrate levels?
3) Is there a significant health risk in due to nitrate levels?

1.5 Research Objective and Hypothesis

1.5.1 General Objective

To determine the level of nitrate in groundwater and health risk assessment in Cherang Melintang Village at Tumpat, Kelantan.

1.5.2 Specific Objective

a) To determine the nitrate level in groundwater.
b) To identify the age, depth and distance of the well from paddy field area.
c) To compare the concentration of nitrate in drinking water with Drinking Water Quality Standard (DWQS).
d) To determine association between age of well, depth of well and distance of well from paddy field area with nitrate level.
e) To determine the health risk associated with nitrate level in groundwater.

1.5.3 Research Hypothesis

High concentration of nitrate from agricultural activity in the groundwater cause health effects to the residents.

1.6 Conceptual Framework

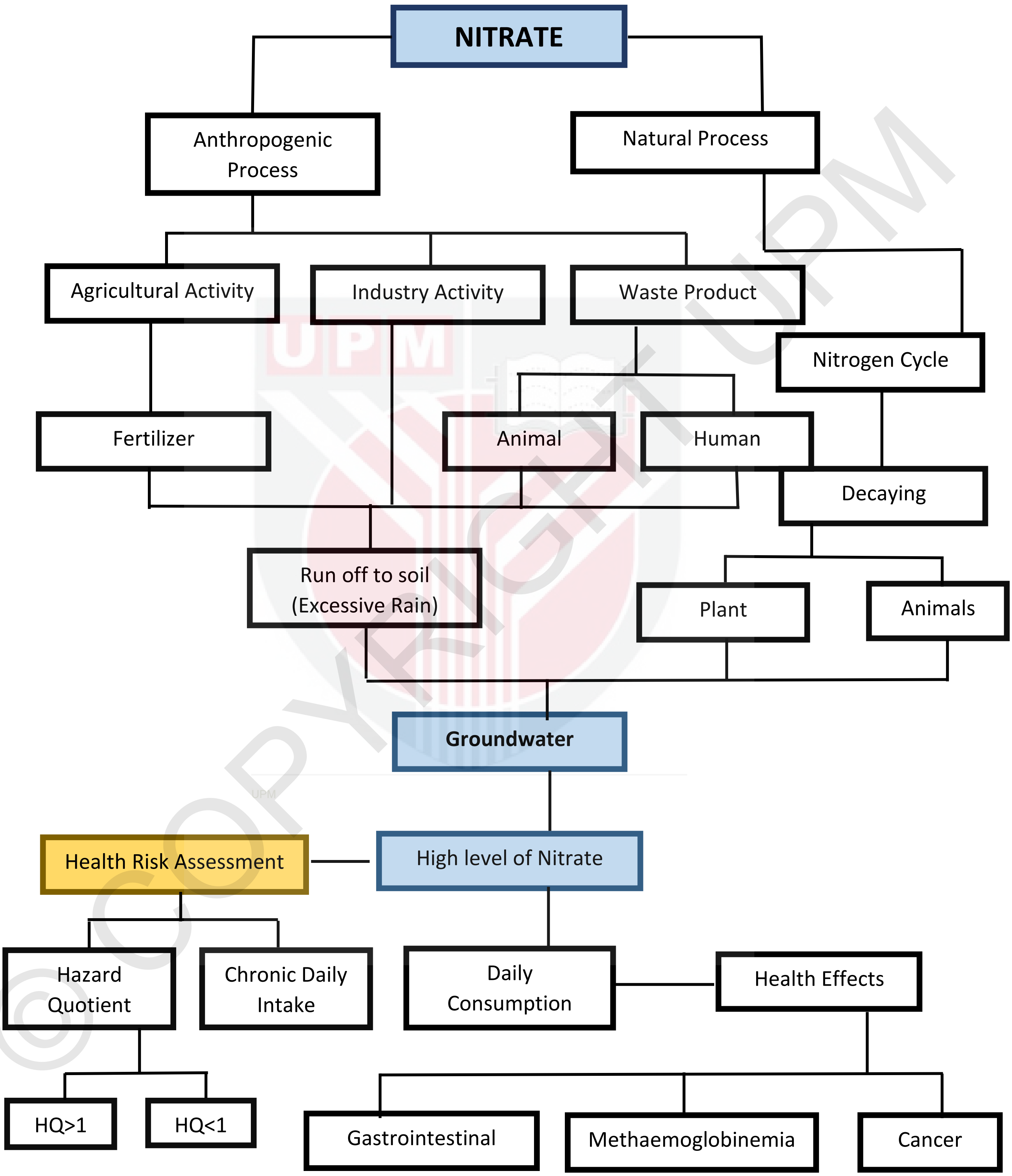

Figure 1.1: Conceptual Framework

1.7 Conceptual Definition

1) **Anthropogenic**

Anthropogenic is the effects, processes, objects, or materials that are caused by human's activity that occur in the environment and significantly affect the biodiversity either directly or indirectly. (European Environment Agency, 2019).

2) **Fertilizer**

Fertilizers are plant nutrient-carrying products that are chemical components that plants need to complete their life cycles. A complete fertilizer contains nitrogen, phosphorus and potassium, which are the primary macronutrients that plants need in large quantities for a growth. (Allen V. Barker, in Encyclopedia of Analytical Science (Third Edition), 2019)

3) **Groundwater**

Groundwater is the water that exists beneath the soil, sand and rock spaces.. It can leach slowly through formations of aquifer. Groundwater can be recharged or replenished when there is heavy rain, water may leach down into the cracks and crevices beneath the land' surface. It also can be contaminated by excessive usage of fertilizer and sewage from septic tank that seeps down to the groundwater. (The Groundwater Foundation, 2019)

4) Health Risk Assessment

Risk assessment is a scientific evaluation of the documented or possible adverse health effects arising from human exposure to the hazard. There is two type of health risk assessment that is qualitative risk assessment and quantitative risk assessment. Quantitative risk assessment is an assessment that emphasizes reliance on numerical expressions. Besides that, qualitative is the characterization of hazard of chemical relatives to others. (WHO, 2019) The process of risk assessment consists of four steps:

a) Hazard identification
b) Hazard Characterization
c) Exposure Assessment
d) Risk Characterization

1.8 Operational Definition

1) Drinking Water

For each respondent, drinking water samples were collected from groundwater sources. There are health threats associated with the ingestion of polluted water with infectious agents, harmful substances and radiological hazards. (WHO, 2019).

2) Nitrate Level

Nitrate concentration from each sample will be analysed by using Portable PH/ORP/ISE Meter model HI98191 and Probe Model HI4113

CHAPTER 2

LITERATURE REVIEW

2.1 Nitrate

Nitrate and Nitrate is occur in nature that become part of nitrogen cycle. Nitrate is formed by anthropogenic process like agricultural activities, industrial waste water discharge and motor vehicle. Nitrate is usually existed in groundwater because it is from the reduction ammonia in soil from plant. Furthermore, nitrate is easily leach into groundwater, so the decomposition of ammonia in soil result in excretion nitrate that will leach to groundwater. (Darvishmotevalli & Moradnia, 2019). Nitrate is highly water-soluble and a similar research has shown that fertiliser nitrate can remain in the soil about more than 50 years upon application and will gradually drain into groundwater systems. (Blaisdell et al., 2019). Furthermore, nitrate have a higher solubility in water and easy to transport to the groundwater this can be prove when Sheikhy, Zaharin, Se, & Keesstra (2017) stated that they use nitrate as an indicator for their study to examine the relationship between changes in land use and groundwater quality.

2.2 Nitrogen Cycle

Nitrogen is one of the essential minerals that all living organisms need to stay alive. Nitrogen is needed by plants when it has been converted from nitrogen gas into ammonia (NH_3) for growth. Nitrogen performs a variety of different ecological cycles, moving from one form to the next as plants and animals use it for growing and, in some cases, for energy. Nitrogen is in the form of organic nutrients (amino acids, DNA) in their tissues when the body excretes and dies. In the phenomenon known as ammonification, numerous fungi and prokaryotes break down the tissue and release inorganic nitrogen directly into the ecosystem.. (Nature Education, 2014).

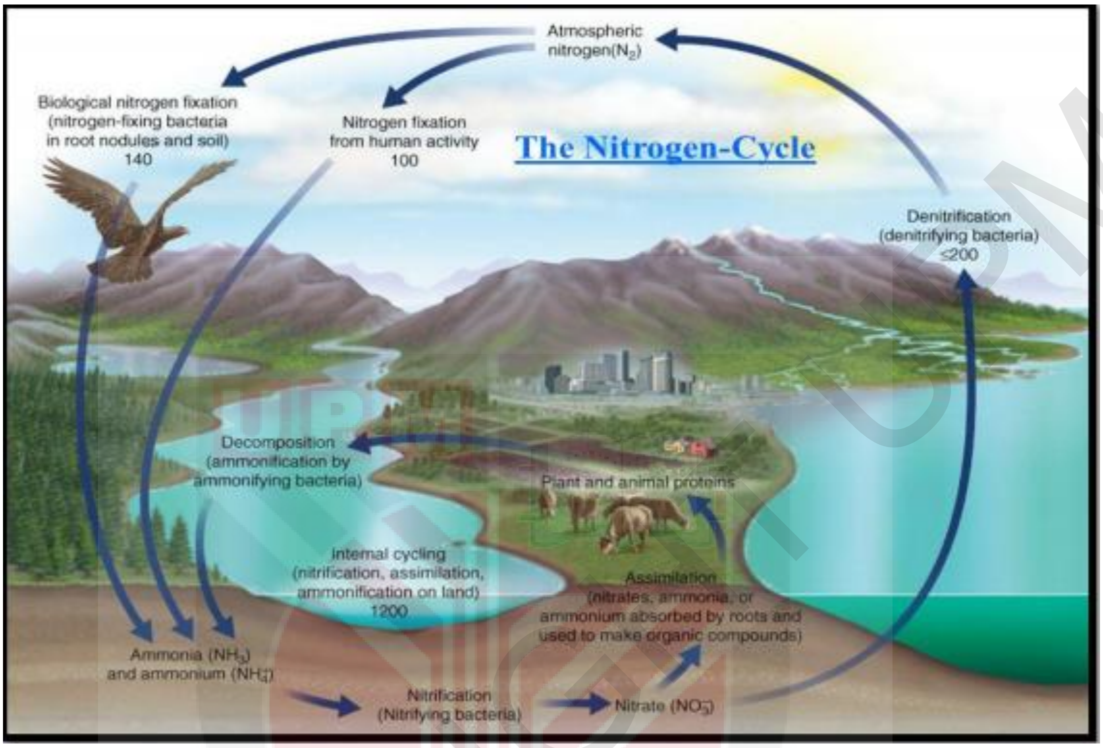

Figure 2.2 Nitrogen Cycle

Source: Environment, 2004

The nitrogen cycle is a biogeochemical cycle that occurs as nitrogen is transformed from nitrogen (N2) to nitrogen that is useful in biological processes. (The Environmental Literacy Council, 2015). Five processes in the nitrogen cycle are nitrogen fixation, nitrogen absorption through organism growth, nitrogen mineralization during degradation, nitrification and denitrification. (Visionlearning, 2019). Humans influence the global nitrogen cycle mainly from the use of nitrogen-based fertilizers.

Nitrogen fixation is a conversion of atmospheric nitrogen to ammonia by nitrogen-fixing bacteria, including cyanobacteria in soil and aquatic environments. Biological nitrogen fixation is very important biological process as it is necessarily needed to sustain food supply to its inhabitants. (Weisany, Raei, & Allahverdipoor, 2014).

Nitrification is the process when ammonium result from decomposition of animal is converted to nitrate (NO_3^-). This cycle includes the presence of oxygen and moving water or the outer layer of surface soils. (Visionlearning, 2019)

Next process is ammonification that is happen when the plants or animals decompose into ammonia that is when nitrogen in the organic matter leach into soil where it braking down by other microorganisms. (The Environmental Literacy Council, 2015).

Denitrification is the process in nitrogen cycle that is when nitrate is converted into gaseous form of nitrogen that is nitrous oxide (N_20) and Nitrogen (N_2). (U. Skiba, in Encyclopedia of Ecology, 2008).

2.3 Source of Nitrate

Agricultural activity can cause nitrate contamination to groundwater and can exceed the permissible allowable amount of nitrate in drinking water. (Shamsuddin et al., 2018). This is because from an agricultural activities, nitrate may leach from agrochemical or by agrochemical that affect soil quality and increase soil nitrate leaching. Furthermore, the source of nitrate are also can contribute from non-agricultural activity that is from septic tank and animal waste. (Nemc & Jazbec, 2017). Besides that, the primary cause of nitrate to the groundwater is from excessive application of fertilizer. The using 500 kg/ha dose of fertilizer will increase the concentration level in the water up to 2km distance from the well. (Nemc & Jazbec, 2017).

Based on Menció et al (2016) stated that the study shows that heavy application of fertilizer, which causes excessive nitrate accumulation in aquifers, then homogenizes the contents of the major dissolved ions.

2.4 Nitrate in Groundwater

In many countries of the world, groundwater is a source of water for agricultural, industrial and domestic purposes. (Hosseinifard et. Al,. 2015). Nitrate can contaminate the groundwater as result of the fertilizer leaches into the soil and rise to the surface of the groundwater. Contamination from agricultural sourceis one of the main concerns for groundwater management. (Menció et al., 2016). Besides that , substances such ad ions, metals, emerging organic contaminants and microorganism that exist in fertilizers also leach into groundwater and can modifying groundwater communities.(Menció et al., 2016). High concentration of nitrate in drinking water, which is obtained directly from wells without any treatment cab be harmful to human health. (He et al., 2016).

2.5 Health Risk Assessment

The United States Environment Protection Agency (USEPA) defines human health risk assessment as a strategic approach to determining the possibility of adverse health consequences in the affected group that may be exposed to specific hazardous substances in the polluted ecological environment, such as water supplies.

2.6 Health Effect Due to Nitrate

2.6.1 Methemoglobinemia

Methemoglobinemia (blue baby) is a disease in new-borns under six months of age that has been the source of concern for people who drink water from long term exposure to nitrate. (Darvishmotevalli & Moradnia, 2019). This is because high concentration of nitrate in drinking water consume by pregnant within the first weeks of pregnancy was implicated with pregnancy complications. (Sadler et al., 2016). Bacteria in the mouth and intestine of the baby reduce the ingested nitrate to nitrite, which is less acidic than adults. It is happens when nitrite binds to hemoglobin to form methemoglobin, interfering with the blood's capacity to carry oxygen.(Ward et al., 2018). Thus, the maximum contaminant level (MCL) for nitrate that is the World Health Organization (WHO) guidelines of 50 mg/L was set to protect against infant methemoglobinemia.(Ward et al., 2018).

2.6.2 Cancer

Consumption of higher concentration of nitrate will increase the risk of certain type of cancer. (Darvishmotevalli & Moradnia, 2019). Exposure to N-nitroso compound (NOSs) produces after drinking water with nitrate contamination can lead to cancer, birth defect and other health effects. (Ward et al., 2018). Molina et al., (2016) find that the risk of cancer from waterborne nitrate in particularly subgroups with other risk factors are high at rated below international guidelines. Ward et al., (2018) stated that the International Cancer Research Agency (IARC) Working Group examined human, animal and mechanistic cancer research from mid- 2006 and found that nitrate and nitrite ingested were likely to be carcinogenic under condition resulting in endogenous nitrosation.

2.6.3 Others

High concentration of nitrate in the surface water also contribute to environment pollution effect from eutrophication. (Nemc & Jazbec, 2017). Besides that, chronic exposure to nitrate have potentially effect the reproductive system. The study have been conducted on animals showed that breast-consuming nitrate / nitrite is able to enter the placenta and impair the developing fetus. There is a different birth defects due to consumption of nitrate including neural tube defects, such as spina bifida and anencephaly and congenital heart defects. (Blaisdell et al., 2019).

CHAPTER 3

METHODOLOGY

3.1 Study Design

The study design was a cross-sectional study to determine the level of nitrate in groundwater at Cherang Melintang Village at Tumpat, Kelantan.

3.2 Study Population

The total population located in Cherang Melintang Village is 3,522 people. They was the respondents who are using groundwater as the main source of drinking water and daily use.

3.3 Study Sample

The analysis was performed on a respondent who fulfils the inclusion criteria only at Cherang Melintang Village at Tumpat, Kelantan. The respondent for this research study will be limited to residents who meet inclusive criteria.

Table 3.1: Inclusive Criteria

Inclusive Criteria	Exclusive Criteria
a) Age 18 years and above b) Long life residents (at least 6 years) c) Using groundwater as their primary source of drinking water supply	a) Use other than groundwater as their source of drinking water supply b) Using water filtration system

3.4 Study Location

The study was carried out in Cherang Melintang Village at Tumpat, Kelantan which lies between latitude 6°14N and 6°09N and longitudes 102°14E and 102°07"E. Tumpat district is located at northern part of Malaysia and it was the smallest district in Kelantan with an area 177 km^2 and had a population of 147,179 people according to the 2010 census. Besides that, and Cherang Melintang Village had population of 3,522 people with 740 living quarters.(Majlis Daerah Tumpat, 2019).

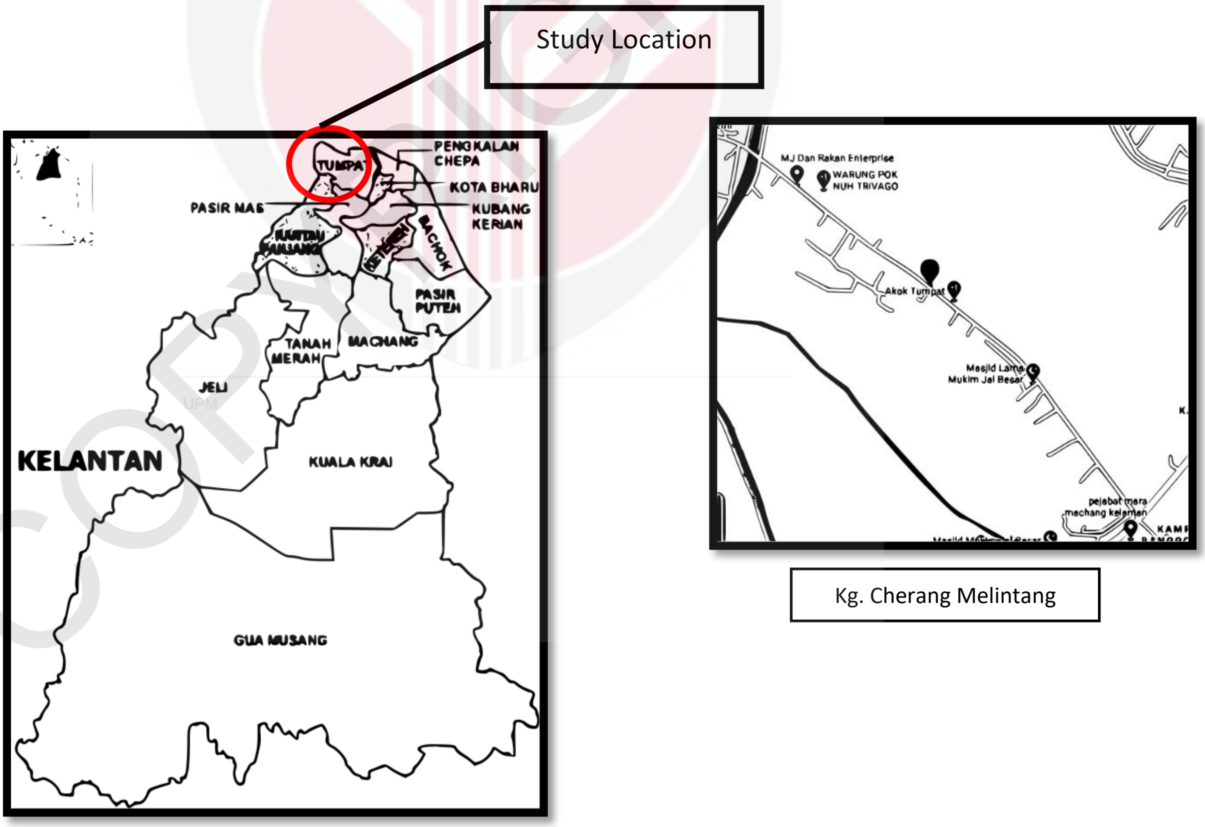

Figure 2.3: Study Location

3.5 Sample Size

The sample size was determined by using formula establishes by Kirkwood and Sterne (2003):

$$N = \frac{p\,(1 - p)}{e^2}$$

Where,

N = Sample size

P = Prevalence

e = Sampling error

Calculation:

$$N = \frac{0.087(1 - 0.087)}{(0.05)^2}$$

$$N = 32$$

Based on the past researched, the prevalence of nitrate level in groundwater which is above 10 mg/L is 8.7%. (Alif Adham Z and Shaharudin MS, 2014). The number of sample size is 32 respondent but, to consider damaged sample, the adjustment for estimated response rate is calculated from 35% of the sample size.

$$\frac{n}{1 - L}$$

Where,

n= Sample size

L= Non-response

$$\frac{32}{1 - 0.35} = 50$$

The sample size required for this study is therefore 50 respondents.

3.6 Sampling Method

Purposive sampling was the sampling method used in this analysis. The respondent was selected on the basis of inclusive and exclusive parameters.

3.7 Study Instrument

3.7.1 Questionnaire

The respondents were given a set of questionnaires to collect information from the selected respondent. The questionnaire consist of three part that is part A the information of the respondents, part B is the source of water supply for daily use and lastly part C for residential area information and health status of the respondents. From this questionnaires, the respondents can be choose by who have comply with the inclusive criteria. This questionnaire was adapted from the Baseline, Descriptive and Time Activity used in the National Human Exposure Assessment Survey (NHEXAS).

3.7.2 Body Weight

The weight of the respondents was weight using digital weighing machine. The reading was taken three times to get an accurate result in unit Kilogram (Kg).

3.7.3 Drinking Water Daily Intake

Standard cup of 200 ml were used to measure daily water intake rate of water among respondents. Respondents will be asked to count up their water intake in a day that will be used to measure the Average Daily Dosage. (ADD).

3.7.4 Global Positioning System (GPS) Mobile Application

Global Positioning System (GPS) Mobile Application was used in this study to determine the distance of well from paddy field area at the study location from each participants.

3.8 Water Sampling

3.8.1 Water Analysis

Water samples were collected from each of the respondents' house by using High Density Polyethylene (HDPE) bottle and replicates bye two times. Next, the nitrate level in the water sample were analysed by using Portable PH/ORP/ISE Meter Model HI98191 and Probe Model HI4113.

Figure 3.1 Portable PH/ORP/ISE Meter Model HI98191

Source : https://hannainst.com

Figure 3.2 Probe Model HI4113

Source : https://hannainst.com

3.8.2 Analysis of Nitrates

Analysis of nitrate in ground water have been done by using Portable PH/ORP/ISE Meter model HI98191 and Probe Model HI4113. Firstly, the probe was assembled and attached to the portable meter. Then, electrolyte solution was refill into probe using dropper just below fill hole and we ensure that there is no bubbles trapped in the probe. Next, the portable meter was calibrated using buffer solution with concentration of 10 ppm. After that, 50 ml of water sample from well water was put into the beaker. The ration of water sample to Ionic strengthen adjuster 50:1 is used to analysed nitrate in water sample. So, 1 ml of ISA (Ionic Strength Adjuster) reagent was added into the beaker in order to elevate the nitrate level. Moreover, the probe was the inserted into the beaker in order to read the nitrate level in the water. These steps were repeated for other water samples that represent different well.

3.9 Quantitative Risk Assessment

Based on the insufficient amount of evidence in humans for the carcinogenicity of nitrate in drinking water because only non-carcinogenic effects of long-term nitrate ingestion in drinking water have been quantified in terms of the risk quotient (HQ) using US EPA health risk assessment model (U.S. EPA Region 6 2005) as shown in (1).

$$HQ = \frac{ADD}{Rfd} \quad \ldots\ldots\ldots (1)$$

Where,

ADD = the sum of nitrate intake via drinking water shown in (2)

Rfd = Nitrate reference dose which is 1.6 mg/kg/day. (IRIS 2012).

$$ADD = C \times IR \times EF \times \frac{ED}{(BW \times AT)} \ldots\ldots\ldots (2)$$

Where,

C = Nitrate Concentration (mg/L)

IR = Intake rate (1L/day for children and 2L/day for adults)

EF = Exposure Frequency (365 day per year)

ED = Exposure Duration (6 years for children and 30 years for adults)

BW = Body Weight (15 kg for children and 60 kg for adults)

AT = Average time (365 days/year x 6 years for children and 365 days/year x 30 years for adults)

An HQ value > 1 indicated a significant non-carcinogenic risk level (U.S. EPA Region 6 2005)

3.10 Data Analysis

The data obtained were analysed by using the IBM SPSS (Statistical Package for the Social Sciences) Version 22. The type of analysis for this study is shown in the table below, based on the objectives of this study.

Table 3.2: Data Analysis

Objectives	Type of analysis
To determine the nitrate level in groundwater.	Descriptive Analysis
To identify the age, depth and distance of the well from paddy field area.	Descriptive Analysis
To compare the concentration of nitrate in drinking water with Drinking Water Quality Standard (DWQS).	One Sample t-Test
To determine the association between age of well, depth of well and distance of well from paddy field area with nitrate level.	Parametric : Pearson Correlation Non-Parametric : Spearman Correlation
To determine the health risk associated with nitrate level in groundwater.	Descriptive Analysis

3.11 Ethical Consideration

a) The respondents were given some explanation about the whole of the study activities involved.

b) Approval letter was given to the respondents to get their consent to be participant in this study.

c) Some explanation was given to the respondents about the health risk assessment that was performed in terms of the objective of the study, the procedure and the right of the respondents in this research.

CHAPTER 4

RESULTS AND DATA ANALYSIS

4.1 Introduction

This chapter presents the findings of this study, which were the data analysis and data that were obtained by using questionnaires completed by the respondents' that use groundwater as their drinking water source. This chapter starts with the profile of the respondents and is accompanied by demographic data. The data were analyse using Spearman Correlation because the data non parametric as sample is not normal.

4.2 Number of Respondents

Table 4.1 shows the total number of respondents' who participated in this study. Based on the sample recorded through the questionnaires that were distributed, female respondents significantly outnumbered male respondents, accounting for 58% and 42% respectively.

Table 4.1 Number of male and female respondents in Cherang Melintang Village

Variables (Gender)	***Frequency, n***	***Percentage, %***
Male	21	42
Female	29	58
Total	50	100

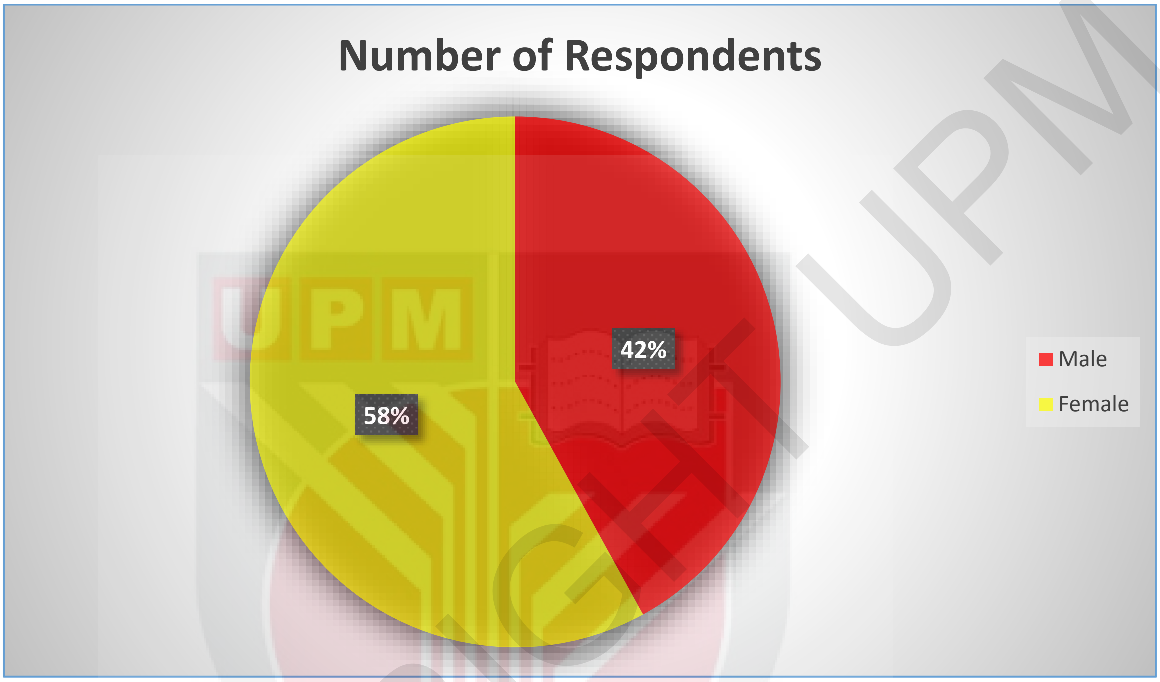

Figure 4.1: Percentage of Respondents

4.3 Weight of the Respondents

From the table 4.2, it shows that the Mean ± S.D of the weight of the respondents' which was 65.44 ± 13.464 (kg) and the respondents' weight range is between 40.0 – 104.0 (kg).

Table 4.2: Weight of the Respondents

Variables	***Mean ± S.D (Kg)***	***Range (Kg)***
Weight	65.44 ± 13.464	40.0 – 104.0

4.4 Characteristics of the well

A detailed overview of age of well, depth of well and distance of well from paddy field of the respondents is presented in Table 4.3. Based on figure 4.2, age of well that are more than 20 years (>20) which is 23 (46%), next is less than 5 years which is 14 (28%), followed by 5 – 10 years that is 8 (16%), 11 – 15 years which is 3 (6%) and 16 – 20 years which 2 (4%).

Besides that, the depth of well was also the information collected through questionnaire and the data was tabulated in table 4.3 and presented in figure 4.3. The majority depth of well of the respondents is 5 – 10 meters which is 30 (60%) and followed by 11 – 15 meters which is 11 (22%), 12 percent were from more than 15 meters and minimum number of respondents came from less than 5 meters depth of well.

Next, the distance between the wells and the nearest paddy field was determine using GPS. The result for mean ± S.D was stated in table 4.3 which is 102.32 ± 31.367 while the range obtained is 40.0 – 200.0 meters.

Table 4.3: The characteristic of wells of the respondents

Variables		*Frequency, n*	*Percentage (%)*	*Mean ± S.D (meters)*	*Range (Meters)*
Age of well					
	< 5 years	14	28		
	5 – 10 years	8	16		
	11 – 15 years	3	6		
	16 – 20 years	2	4		
	> 20 years	23	46		
	Total	50	100	3.24 ± 1.779	
Depth of Well					
	< 5 meters	3	6		
	5 – 10 meters	30	60		
	11 – 15 meters	11	22		
	> 15 meters	6	12		
	Total	50	100	2.40 ± 0.782	
Distance of Well from Source of Nitrate (meters)		**50**	**100**	**14.04±8.425**	**5 – 50**

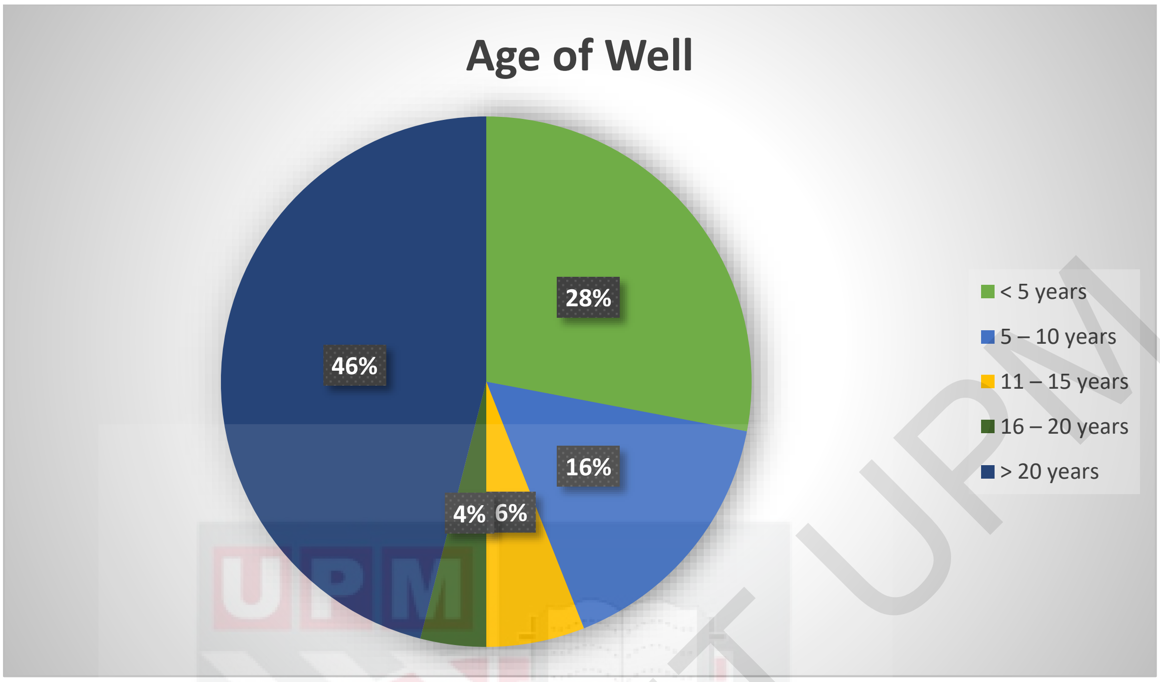

Figure 4.2: Age of well

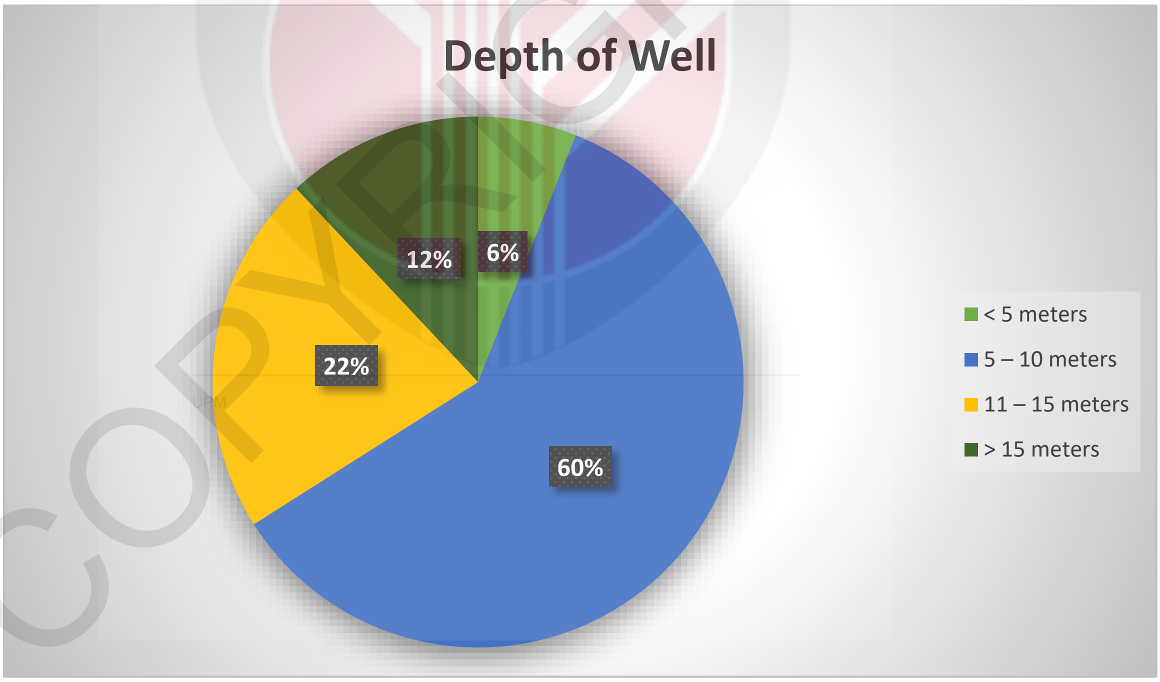

Figure 4.3: Depth of well

4.5 Nitrate Level in Groundwater

The value that was used for data collection was in nitrate (NO^{3-}) level. Table below shows that Mean ± S.D was 2.91 ± 2.57, while the range was from 0.42 – 8.78 ppm. The amount of nitrate obtained was below than maximum acceptable value which is 10 mg/L nitrate- N.

Table 4.4: Nitrate level in groundwater

Variables	*Mean ± S.D (ppm)*	*Range (ppm)*
Nitrate	2.91 ± 2.57	0.42 – 8.78

4.6 Comparison of nitrate level for each samples with standard

Accordance to the National Drinking Water Quality (NDWQ), the maximum acceptable nitrate level in drinking water is 10 mg/L. Based on figure 4.4, nitrate level were below the maximum acceptable value of NDWQS from all samples.

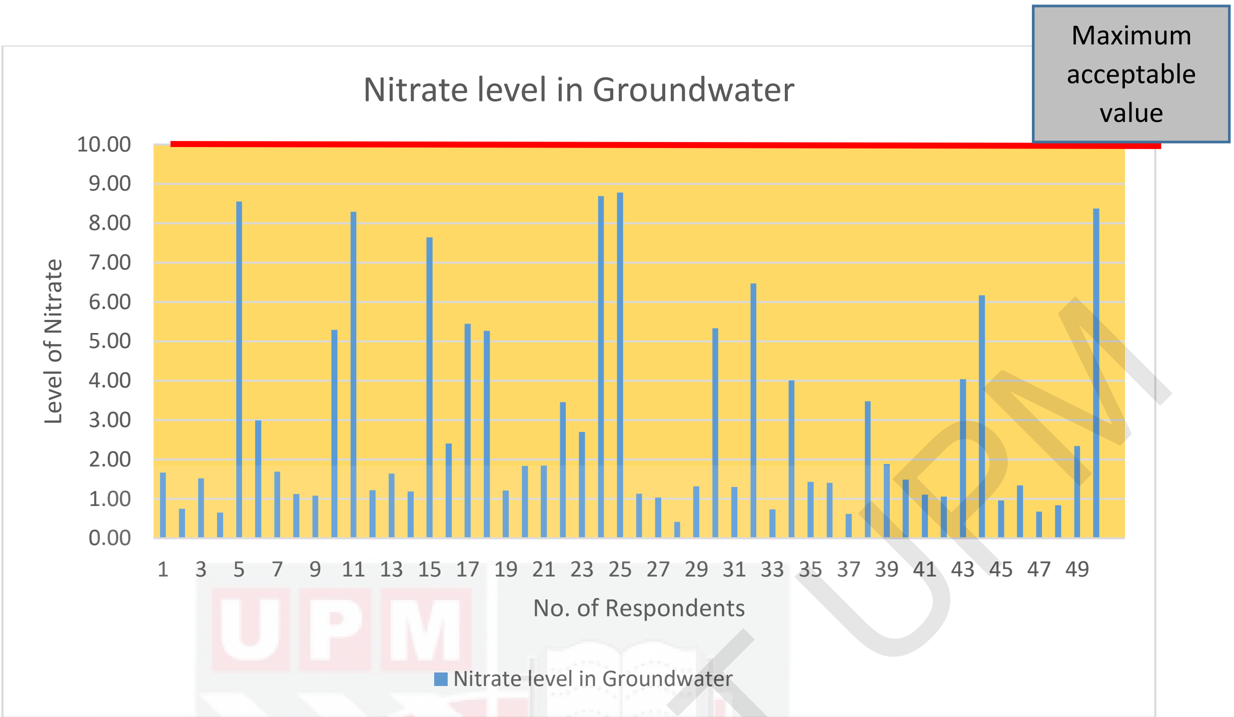

Figure 4.4: Comparison of Nitrate Level with National Drinking Water Quality Standard

4.7 The association between distance of well from source of nitrate with nitrate level (Spearman Rho Correlation test)

In this research, the test used to determine the correlation between well age, well depth and well distance from the paddy field with nitrate level is Spearman Rho Correlation test due to the non-parametric value of nitrate level. From the statistical analysis, neither age (years) nor depth (meter) had no significant correlation with nitrate level is above 0.05 ($p > 0.05$). Indeed, there is a significant correlation between distance of well from source of nitrate (meter) and nitrate level ($p < 0.05$) with the coefficient of correlation, r = - 0.40.

Table 4.5: Spearman Rho Correlation Test

Variable	*Nitrate Level*	
	r	***P - value***
Distance from source of nitrate	- 0.40	0.04
Age of wells	0.25	0.81
Depth of wells	- 0.37	0.79

4.8 Average Daily Dose (ADD)

The Average Daily Dose (ADD) estimation value of the respondents was calculated based on the equation stated in Chapter 3 and was tabulated in table 4.6. The result showed that, the Mean ± SD for ADD was 0.09 ± 0.08 (mg/kg/day) and obtained a range between 0.01 – 0.29 (mg/kg/day).

Table 4.6: Average Daily Dose (ADD) estimation value

Variables	*Mean ± S.D (ppm)*	*Median*	*Range (ppm)*
Nitrate Level	2.91 ± 2.57	1.65	0.42 – 8.78
Average Daily Dose	0.09 ± 0.08	0.09	0.01 – 0.29

4.9 Hazard Quotient (HQ) estimation

The Hazard Quotient (HQ) was calculated to estimate the non-carcinogenic risk which the respondents exposed. The result of Hazard Quotient (HQ) is tabulated in table 4.6 which showed that Hazard Quotient (HQ) was less than 1 (HQ < 1) for all respondents. This indicated that there is no risk from nitrate exposure to the respondents.

Table 4.7: Hazard Quotient (HQ) estimation value

Hazard Quotient (HQ)	*No. of Respondents, n*	*Percentage (%)*
HQ < 1	50	100
HQ > 1	0	0

CHAPTER 5

DISCUSSION

5.1 Characteristics of Wells

The three characteristics of the wells collected were age, depth and distance from the nitrate source which is from the sewage and paddy area. All this variables have been described in this study as potentially leading to the effect of nitrate levels in groundwater. (Swistock et al., 2009).

The depth of well were collected because in past study by Lockhart et al., (2013) found that the shallow wells are more likely to be impacted by high nitrate levels than deep wells. This show that the depth wells is likely affected the level of nitrate in groundwater. Furthermore, the age of well also affected the level of nitrate in groundwater because usually shallow wells will contribute to nitrate enriched in groundwater.

Besides that, the distance of well to the source nitrate also can contribute to elevated nitrate level in the groundwater. Based on study by Ki et al., (2015), they stated that an important factor in nitrate exposure is the distance between the wells and contaminant sources. Besides that, the main source of nitrate to the groundwater is from excessive using of fertilizer. Furthermore, the source of nitrate are also can contribute from non-agricultural activity that is from septic tank and animal waste. (Nemc & Jazbec, 2017).

5.2 Nitrate Level in Groundwater

Based on result in table 4.4, the Mean ± SD of the nitrate level was 2.91 ± 2.57 ppm, while the range was from 0.42 – 8.78 ppm. The concentration of nitrate in Cherang Melintang Village was below than maximum acceptable value which is 10 mg/L nitrate- N.

Data collection was conducted during rainy season, so this will result in excessive surface water that will affect the concentration of nitrate in groundwater. Ki et al., (2015) stated that the concentration of nitrate in groundwater was dominated more through hydrological processes than through biochemical process which is seasonally variable rainfall and irrigation patterns.

Even though the concentration of nitrate was below than maximum acceptable value, the data for nitrate level in Cherang Melintang Village is almost exceed the maximum acceptable value. This is because the data collection was conducted during rainy season which will affected the concentration of nitrate in groundwater when nitrate which had accumulated in the soil during the dry season can be transported to the groundwater. (Ki et al., 2015). A study conducted by Wang et al., (2015) found that nitrate concentrations in groundwater will increase during the early rainy season, decrease during the rainy season and remain constant during the dry season.

Besides that, most of the wells at Cherang Melintang village was built near the septic tank, which is one of the source of nitrate contamination in groundwater. A study in Mashhad, Iran, found that urea hydrolysis in human waste that happen in sewage was the main cause of nitrate pollution (Zendehbad et al., 2019). This is because urea hydrolysis in human sewage undergoes the NH4+ nitrification cycle and result in nitrate accumulation in groundwater.

5.3 Comparison with National Drinking Water Quality (NDWQ)

In Malaysia, the nitrate level standard as stated in Malaysian National Drinking Water Quality Standard (NDWQS) is 10 mg / L nitrate-N. Based on the data that was collected during January 2020, the concentration of nitrate in the study area's groundwater was below the Malaysian National Drinking Water Quality Standard

(NDWQS) Maximum Permissible Limit and the USEPA International Standard (10 mg L−1). (Jamaludin, Sham, Norkhadijah, & Ismail, 2013). Besides that, a similar study conducted at Bachok and Kota Bharu, Kelantan by Alif & Shaharuddin (2014) and Amirah et al., (2014) also stated that the concentration of nitrate level in groundwater did not exceed the maximum level of nitrate in drinking water by National Drinking Water Quality (NDWQ).

Nitrate absorption by crops as a nutrient is responsible for nitrate levels in groundwater. So, the concentration of nitrate is low potentially due to inadequate application of nitrate fertilizers to crops, which prevents the leaching of excess nitrate into groundwater. (Jamaludin et al., 2013). Shams et al. (2009) stated that the weather factor should be considered because it could affect chemical (nitrate) concentration in groundwater. Furthermore, data was collected during the rainy season which may affect nitrate accumulation in groundwater. (Ki et al., 2015).

5.4 The association between age of well, depth of well and distance of well from source of nitrate with nitrate level (Spearman Rho Correlation Test)

Data analysis in Table 2 showed that there was no significant correlation between age and depth of wells with nitrate level. These findings were different from study conducted by Lasagna et al., (2016) that increasing in depth of wells will reduce nitrate concentration in the groundwater. It is because water is drawn from a shallow aquifer for domestic and agricultural use that is exposed to a high risk of nitrate due to human activities on the soil. (Shamshuddin et al., 2013). Furthermore, deep wells usually experience low nitrate concentrations due to a high level of protection of natural surface pollutants relative to shallow aquifers. (Lasagna et al., 2016). In addition, a study conducted at San Joaquin Valley in California by Lockhart et al., (2013) showed that nitrate levels decrease significantly as well as increase in depth. Besides, the data for age of well shows that it was no significant correlation with level of nitrate in groundwater which is in line with the analysis carried out by Shaharuddin et al., (2019).

On the other hand, there was a significant correlation between the distance of wells from the source of nitrate with a strong negative linear correlation (r = -0.41). Previous studies by Nemc & Jazbec, (2017), Huan et al., (2020) and Nemčić-Jurec et al., (2013) stated that there was a significant correlation between distance of wells and the point source of nitrate pollution. It was also stated that nitrate levels in groundwater at a distance of 6m from the source of nitrate was twice higher compared to wells located 60m from the contamination.

5.5 Health Risk Assessment (Hazard Quotient)

From the result obtained, Average Daily Dose (ADD) estimation for the respondents had 0.09 ± 0.08 (mg/kg/day) for Mean ± SD and acquired a range between 0.01 – 0.29 (mg/kg/day). Then, the result was used to calculate Hazard Quotient (HQ) using the equation stated in Chapter 3. The Hazard Quotient (HQ) values for all respondents shown in this analysis were less than 1 (HQ<1). This indicates that the risk was acceptable to all respondents.

A study conducted by (Pawełczyk, 2012) also stated that the Hazard Quotient (HQ) for all respondents who consumed drinking water contaminate with nitrate is below than 1, so this indicated that there is no risk from nitrate exposure to the respondents. Besides, a study conducted at Bachok, Kelantan also stated that the groundwater is safe for consumption in case of nitrate exposure because the Hazard Quotient is below than 1. (Aida Soraya, 2018)

CHAPTER 6

CONCLUSION, LIMITATION AND RECOMMENDATION

6.1 Conclusion

Nitrogen in water can initiate from both natural and anthropogenic source that can reach surface water and groundwater. Nitrate can easily move through water and soil when there is excessive rainfall and excessive nitrate from agricultural fertilizer. When high amount of inorganic nitrogen is use as fertilizer in a rice cultivation, the fertilizer will be decomposed to an ammonia and it will be oxidized to nitrite and nitrate. Nitrogen from fertilizer will easily move to the groundwater and high concentration of nitrate in groundwater will affect the residents who use groundwater as their source of drinking water. Sewage also be a source of nitrate in groundwater which urea hydrolysis in human waste was the main cause of nitrate pollution (Zendehbad et al., 2019). This is because urea hydrolysis in human sewage undergoes the NH4+ nitrification cycle and result in nitrate accumulation in groundwater.

This study found that the nitrate level in drinking water at Cherang Melintang Village, Tumpat Kelantan was below than Maximum Acceptable Value of nitrate which is 10 ppm. This shows that in the case of nitrate, resident Cherang Melintang Village can still consume drinking water source from groundwater because the result obtained for Hazard Quotient (HQ) was lower than 1. This indicates that there was no adverse health impact on residents due to nitrate exposure. Nevertheless, the nitrate content in groundwater varies from time to time and is likely to reach the maximum acceptable value.

6.2 Limitation

First, the sample size in this study cannot represent the entire Tumpat district of Kelantan. Nevertheless, the data obtained could be a guideline value for nitrate level in Tumpat, Kelantan for future study.

Next, the data for nitrate in groundwater was collected only in planting phase but for paddy field, there a three phase which is pre planting phase, planting phase and harvesting phase. This is because of time constraint to continue this study.

6.3 Recommendation

A study to conduct a health risk assessment of respondents who consume contaminated drinking water should be a case-control studies because drinking water nitrate and cancer need to obtained lifetime residence and drinking water source histories, whereas cohort studies typically have collected only the current water source. This studies lacked information about study participants' water consumption, which may be an important determinant of exposure to drinking water contaminants.

6.4 Acknowledgement

First and foremost, Alhamdulillah, most grateful to Allah S.W.T for giving me a strength and good health in completion of this thesis.

I also would like to thank to my supervisor, Dr Shaharuddin Bin Mohd Sham for giving endless guidance and positive encouragement to finish this thesis. It has been a great pleasure and honour to have him as my supervisor. Next, I also would like to thank to Environmental Health Laboratory, Department of Environmental and Occupational Health, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia for provide me and instrument and tools for my data collection.

I would also would like to thanks to residents in Cherang Melintang Village at Tumpat, Kelantan who involve in this research for giving their time and help me during data collection. Besides, I also would like to thanks to Tumpat District Health Office for helping me in providing a data of resident in Tumpat, Kelantan.

Lastly, my deepest gratitude goes to my family, my groupmates and colleagues for giving support to completion of this study.

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APPENDIX 1

JAWATANKUASA ETIKA UNIVERSITI UNTUK PENYELIDIKAN MELIBATKAN MANUSIA (JKEUPM)
UNIVERSITI PUTRA MALAYSIA, 43400 UPM SERDANG, SELANGOR, MALAYSIA

FORM 2.4: RESPONDENT'S INFORMATION SHEET AND INFORMED CONSENT FORM

Please read the following information carefully and do not hesitate to discuss any questions you may have with the researcher.

1. STUDY TITLE :
A Cross-Sectional Study on Nitrate In Groundwater and Its Health Risk Assessment Among Residents In Tumpat, Kelantan.

2. INTRODUCTION:
Nitrogen in water can initiate from both natural and anthropogenic source that can reach surface water and groundwater. Nitrate can easily move through water and soil when there is excessive rainfall and excessive nitrate from agricultural fertilizer. When high amount of inorganic nitrogen is use as fertilizer in a rice cultivation, the fertilizer will be decomposed to an ammonia and it will be oxidized to nitrite and nitrate. (Guidelines & Quality, n.d.). Nitrogen from fertilizer will easily move to the groundwater and high concentration of nitrate in groundwater will affect the residents who use groundwater as their source of drinking water.

3. WHAT WILL YOU HAVE TO DO?
Respondents need to answer a set of questionnaire and the questionnaire consist of three part that is part A the information of the respondents, part B is the source of water supply for daily use and lastly part C for residential area information and health status of the respondents.

4. WHO SHOULD NOT PARTICIPATE IN THE STUDY?
The respondents with the age range below 18 years old, do not use groundwater as their source of water and use filtration system in their houses.

5. WHAT WILL BE THE BENEFITS OF THE STUDY:

(a) TO YOU AS THE SUBJECT?

The benefits of this study is we can identify whether the level of nitrate in groundwater is safe for daily use or not.

(b) TO THE INVESTIGATOR?

We can determine if there is the association between the usage of nitrate fertilizer in paddy field with the level of nitrate in groundwater.

6. WHAT ARE THE POSSIBLE RISKS?

There is no posible risks will happen to the respondents.

7. WILL THE INFORMATION THAT YOU PROVIDE AND YOUR IDENTITY REMAIN CONFIDENTIAL?

Yes, all the information about respondents will be kept internally and confidentially.

8. WHO SHOULD YOU CONTACT IF YOU HAVE ADDITIONAL QUESTIONS DURING THE COURSE OF THE RESEARCH?

Dr Shaharuddin Bin Mohd Sham,

Department of Environmental and Occupational Health,

Faculty of Medicine and Health Sciences,

Universiti Putra Malaysia,

Phone No. : 012-3387305

Office No. : 03-97692407

Email : shaha@upm.edu.my

9. CONSENT

I .... Identity Card No. ....

address...

....hereby voluntarily agree to take part in the research stated above *(clinical /drug trial/video recording/ focus group/interview-based/ questionnaire-based).

I have been informed about the nature of the research in terms of methodology, possible adverse effects and complications (as written in the Respondent's Information Sheet). I understand that I have the right to withdraw from this research at any time without giving any reason whatsoever. I also understand that this study is confidential and all information provided with regard to my identity will remain private and confidential.

I* wish / do not wish to know the results related to my participation in the research

I agree/do not agree that the images/photos/video recordings/voice recordings related to me be used in any form of publication or presentation (if applicable)

* delete where necessary

Signature .... (Respondent)

Date :..

Signature .... (Witness)

Name :...

I/C No. :...

I confirm that I have explained to the respondent the nature and purpose of the above-mentioned research.

Date ....

Signature .... (Researcher)

APPENDIX 2

ETHICS COMMITTEE FOR RESEARCH INVOLVING HUMAN SUBJECTS (JKEUPM)
UNIVERSITI PUTRA MALAYSIA

Research title	:	**A Cross-Sectional Study on Nitrate in Groundwater and its Health Risk Assessment among Residents in Tumpat, Kelantan.**
Study Site	:	**Kampung Bunohan and Kampung Cherang Melintang, Tumpat, Kelantan.**
JKEUPM Ref No.	:	**JKEUPM-2019-434**
Researcher	:	**Muhammad Faiz Afzal Mohd Zaki**
Supervisor	:	**Dr. Shaharuddin Mohd Sham**

Documents received and reviewed with reference to the above study:

1. Ethics Application Form, Version 1 dated 25/10/2019
2. Respondent Information Sheet & Consent (English), Version 2 dated 18/12/2019
3. Proposal (English), Version 1 dated 25/10/2019
4. Questionnaires/ Interviews (Malay), Version 1 dated 25/10/2019
5. Curriculum Vitae of:
   a. Dr. Shaharuddin Mohd Sham

The University Research Ethics Committee, Universiti Putra Malaysia (JKEUPM) operates in accordance to the ICH-GCP Guidelines.

Decision by JKEUPM:

[X] Approved

[X] **Permission MUST BE OBTAINED from the respective hospitals/ institutions before conducting the research**

[ ] Disapproved

Please note that the approval is **VALID UNTIL 6 JANUARY 2021**

Researchers should comply with the following:

I. Complete a Study Final Report upon study completion (Form 3.2).

II. Ethical approval is required in the case of amendments/ changes to the study documents/ study sites/ study team.

III. Applicable for Clinical Trial Studies and Clinical interventional Studies only: Progress Report has to be submitted to JKEUPM at every 6 months from the date of approval (Form 3.1). Report

APPENDIX 3

BORANG SOAL SELIDIK

Semua maklumat adalah untuk kegunaan kajian sahaja dan maklumat ini akan dianggap sulit. Maklumat anda hanya digunakan untuk membahagi responden mengikut kategori yang sama.

Arahan: Sila jawab semua soalan dan tandakan (/) pada ruang yang disediakan.

Bahagian A: Maklumat responden

No ID : ☐☐☐☐☐☐☐☐☐☐

Umur : ☐☐ tahun

Jantina : ☐ Lelaki ☐ Perempuan

Pekerjaan : ....

Pendapatan Sebulan : RM ....

Taraf Pendidikan :

☐ Tidak bersekolah

☐ Sekolah rendah

☐ Sekolah menengah

☐ Universiti

☐ Lain-lain

Berat : .... kg

Bahagian B: Maklumat penggunaan air paip

Apakah punca air paip di rumah?

☐ Air Kelantan SB ☐ Bawah Tanah ☐ Kedua-duanya ☐ Lain-lain, sila nyatakan:

Jika kedua-duanya, yang manakah yang lebih digunakan: ☐ AKSB ☐ Bawah Tanah ☐ Sama rata

Berapa gelas air yang anda minum setiap hari? .... gelas (200 ml)

Penggunaan air dari dapur: ☐ Memasak ☐ Minum ☐ Kegunaan domestik ☐ Lain-lain,

sila nyatakan ....

Adakah anda berpuas hati dengan kualiti air paip yang digunakan? ☐ Ya ☐ Tidak ☐ Tidak Pasti

Adakah anda menggunakan sistem penapisan air persendirian di rumah? ☐ Ya ☐ Tidak

Jika ya, sila nyatakan jenama yang digunakan: ....

Bahagian C: Maklumat persekitaran tempat tinggal

Adakah terdapat kawasan pertanian berdekatan dengan tempat tinggal anda?

☐ Ya ☐ Tidak ☐ Tidak pasti

Apakah jenis perpaipan air di rumah? ☐ Logam ☐ PVC ☐ Tidak pasti

Umur Telaga ☐ < 5 Tahun ☐ 5-10 Tahun ☐ 10-15 Tahun ☐ 16-20 Tahun ☐ > 20 Tahun

Kedalaman telaga (m) ☐ < 5 m ☐ 5-10 m ☐ 11-15 m ☐ >15 m

Jenis telaga ☐ Terbuka ☐ Tertutup ☐ Boring ☐ Lain-lain, sila nyatakan ....

Bagaimana air diambil daripada telaga? ☐ Menggunakan baldi ☐ Pam elektrik ☐ Lain-lain, sila nyatakan................

Bahagian D: Maklumat Kesihatan

Adakah anda mempunyai masalah kesihatan serius: ☐ Ya ☐ Tidak

TERIMA KASIH ATAS KERJASAMA ANDA
-TAMAT-

NAMA PENUH RESPONDEN	
NOMBOR RUMAH	
NAMA JALAN	
NAMA KAMPUNG	
JARAK DARIPADA SAWAH/SISTEM SEPTIK (M)	
KOORDINAT GEOGRAFI	
MAKLUMAT TAMBAHAN	
TANDATANGAN ENUMERATOR & TARIKH	

APPENDIX 4

Pictures during data collection in study area.