UNIVERSITI PUTRA MALAYSIA

NITRATE LEVELS IN WELL WATER AND POPULATION HEALTH RISK OF DIFFERENT PLANTING PHASES OF PADDY IN KOTA BHARU AND BACHOK, KELANTAN MALAYSIA

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FPSK(m) 2014 47

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

December 2014

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Many researchers found an exposure to nitrate increase the risk getting a cancer. Uncontrolled application of fertilizers on crops cause the excess nitrate to leach into groundwater. This study was conducted to determine the nitrate levels in well water located within 100 meter from paddy farming area in three planting phase. We also determined the health risk associated with the population who used this well water. This study involved 80 wells in Kota Bharu and Bachok Kelantan. Well water samples were analyzed using YSI Professional Plus for nitrate levels while the health risk was calculated using the hazard index formula. Questionnaire was used to obtain the information of the health status of respondents. The mean ± standard deviation (SD) of nitrate levels in Kota Bharu and Bachok was 2.69 ± 2.43 mg/L and 4.02 ± 3.85 mg/L respectively, which was below the national standards (10 mg/L). In general, nitrate concentration higher in planting season with the mean ± SD of 4.63 ± 4.84 mg/L as compared to the pre-planting phase (2.84 ± 2.26 mg/L) and harvesting phase (2.51 ± 2.90 mg/L. The highest nitrate concentration was determined in Bachok during the planting season with the mean ± SD of 6.58 ± 5.89 mg/L. The hazard index for the studied population was less than 1 and ranged between 0.013 and 0.123. There were no respondents reported with gastric cancer cases. In conclusion, the level of nitrate in well water of Kota Bharu and Bachok is tolerable and the population has minimal health risk.

Abstrak tesis yang dikemukan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

KANDUNGAN NITRAT DALAM AIR TELAGA DAN RISIKO TERHADAP KESIHATAN POPULASI PADA MUSIM PENANAMAN PADI YANG BERBEZA DI KOTA BHARU DAN BACHOK, KELANTAN, MALAYSIA.

Oleh

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Penyelidik-penyelidik mendapati bahawa pendedahan kepada nitrat akan meningkatkan risiko terhadap penyakit kanser. Penggunaan baja tanaman yang tidak terkawal menyebabkan kandungan nitrat yang berlebihan mengalir ke dalam air bawah tanah. Kajian ini dijalankan bagi menentukan aras nitrat dalam air bawah tanah yang terletak brhampiran kawasan penanaman padi dengan jarak kurang atau sama dengan 100 meter pada musim pananaman yang berbeza. Kajian ini juga turut dijalankan bagi menentukan risiko kesihatan responden yang menggunakan air telaga yang di kaji. Kajian ini melibatkan 80 buah telaga di sekitar daearah Kota Bharu dan Bachok, Kelantan. Sampel air telaga yang diambil di analisis menggunakan alat YSI Professional Plus bagi menentukan kandungan nitrat dalam sampel air telaga tersebut. Manakala, risiko kesihatan di kira menggunakan formula indek bahaya. Soal selidik juga dijalankan bagi mendapatkan maklumat berkaitan status kesihatan responden yang terlibat. Hasil kajian mendapati bahawa purata kandungan nitrat di Kota Bharu dan Bachok adalah masing-masing 2.69±2.43 mg/L and 4.02 ± 3.85 mg/L di mana masih di bawah aras piawai. Secara keseluruhannya, kandungan nitrat pada fasa penanaman adalah lebih tinggi dengan bacaan 4.63 ± 4.84 mg/L berbanding dengan fasa yang lain iaitu fasa awal penanaman (2.84±2.26 mg/L) dan fasa penuaian (2.51±2.90 mg/L). Kandungan nitrat adalah paling tinggi di daerah Bachok semasa musim penanamam dengan bacaan 6.58 ± 5.89 mg/L. Index bahaya bagi populasi dalam kajian ini dicatatkan kurang daripada 1 dan dalam lingkungan 0.013 dan 0.123. Dalam kajian ini tiada responden yang pernah dilaporkan mempunyai penyakit kanser perut. Sebagai kesimpulan, kandungan nitrat dalam air telaga di daerah Kota Bharu dan Bachok adalah terkawal dan populasi ini mempunyai risiko kesihatan yang rendah.

ACKNOWLEDGEMENTS

Assalamualaikum w.b.t

Alhamdulillah, I express my first and foremost gratitude to the most Merciful Allah S.W.T for giving me knowledge, strength and blessing to complete this study. I take this opportunity to extend my gratitude to my dedicated supervisor Dr. Sharifah Norkhadijah Syed Ismail and co-supervisor Dr. Shaharuddin Mohd Sham who has been a great mentor in this journey. I highly appreciated them for giving unlimited effort in supervising my research, offering their valuable expertise and time for advising me at all times. I would like to thank all the lectures and staff at Department of Environmental and Occupational Health on their help and assistance while conducting the laboratory work. Special thanks to the officers from Kemubu Agricultural Department Authority (KADA) for their valuable cooperation during my sampling period in Kelantan and all friendly respondents that involved excellently in this study. My deep appreciation and gratitude to my dearly family members and friends especially my beloved husband Muhamad Fakrulrozhi Bin Mohamad Sabri and daughter Amni Fatehah for being patient with me and give me unlimited support. Special thanks to my parents Ahmad Roslan bin Abdul Yazid and Farihah Muhamad, thank you for being wonderful mom and dad, encouragement and undying love. Also for father and mother in law Muhamad Sabri Bin Di and Rohana Md Taib and siblings Nur Mahfuzah, Siti Fathimah, Siti Khodijah, 'Ainin Sofia, Muhammad Multazam, Anis Najihah, Muhammad Al-Amin, NurNadiatul Balqis and Ahmad Yassin who always had been there through this effort and struggle up and down with prayers and moral support. Thousands of thanks for the unlimited supports, undying love and care. Thank you.

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science**.** The members of the Supervisory Committee were as follows:

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TABLE OF CONTENTS

			Page
ABSTRACT			i
ABSTRAK			ii
ACKNOWLEDGEMENTS			iii
APPROVAL			iv
DECLARATION			vi
LIST OF TABLES			xi
LIST OF FIGURES			xii
LIST OF ABBREVIATIONS			xiii
CHAPTER			
1	**INTRODUCTION**		
	1.1	Introduction	1
	1.2	Problem Statement	2
	1.3	Objectives of Study	4
	1.4	Hypothesis	4
	1.5	Conceptual Framework	4
	1.6	Scope of Study	7
	1.7	Significance of Study	7
	1.8	Terms Definition	7
2	**LITERATURE REVIEW**		
	2.1	Introduction	9
	2.2	Groundwater	9
	2.3	Well Description	11
		2.3.1 Well Type	11
	2.4	Groundwater Quality	12
	2.5	Groundwater Pollution	13
	2.6	Nitrate	13
		2.6.1 Nitrogen Cycle	14
		2.6.2 Nitrogen Contamination in Groundwater	15
	2.7	Guideline for Nitrate in Groundwater	16
	2.8	Agriculture Activity and Nitrate in Environment	18
		2.8.1 Paddy Field	18
	2.9	Paddy Planting	18
		2.9.1 Pre-planting Phase	19
		2.9.2 Planting Phase	19
		2.9.3 Harvesting Phase	20
	2.10	Health Effects	21
		2.10.1 Gastric Cancer	22
		2.10.2 Methemoglobinemia	25
		2.10.3 Non-hodgkins' Lymphoma	25
	2.11	Health Risk Assessment	25
		2.11.1 Advantages and Disadvantages of HRA	26
	2.12	Conclusion	27
3	**METHODOLOGY**		
	3.1	Introduction	28
	3.2	Description of The Study Area	
		3.2.1 Introduction To Kota Bharu and Bachok	28
		3.2.2 Meteorology and Hydrology	30
		3.2.3 Soil Types in Study Area	31

	3.2.4	Land Use in Study Area	32
	3.2.5	Topography	33
	3.2.6	Geology	34
3.3	Hydrogeology		36
	3.3.1	Groundwater Status in the Study Area	36
	3.3.2	Aquifer Characteristics	37
3.4	Research Flow		38
	3.4.1	Study Design	38
3.5	Study Population		39
	3.5.1	Sample Size Calculation	39
3.6	Sampling Method		40
3.7	Well Water Sample Collection		42
3.8	Instruments		
	3.8.1	YSI Professional Plus	46
	3.8.2	Weighing Scale	46
	3.8.3	Tap Meter	46
	3.8.4	Questionnaire	47
3.9	Geographical Information System (GIS) Analysis		47
	3.9.1	Kriging Method	47
3.10	Health Risk Assessment (HRA)		47
3.11	Quality Assurance and Quality Control		48
3.12	Data Analysis		48
3.13	Ethical Issues		49
3.14	Study Limitation		49
3.15	Summary		49
4	**RESULTS AND DISCUSSION**		
4.1	Introduction		50
4.2	Socio-demographic Background of Respondents		50
4.3	Well Characteristics		52
4.4	Nitrate Levels in Well Water of Kota Bharu in Different Planting Phase		54
4.5	Nitrate Levels in Well Water of Bachok in Different Planting Phase		60
4.6	The Comparison of Nitrate Levels in Kota Bharu and Bachok During Different Planting Phase		65
4.7	Comparison of Nitrate Levels in Kota Bharu and Bachok to the National Drinking Water Quality Standard in Three Planting Phase		66
4.8	The Relationship of Nitrate Levels with Physicochemical Properties of the Well Water		69
4.9	The Relationship Between Well Background and Nitrate Levels		70
4.10	Respondent's Perceived Health Symptoms and Respondents Satisfaction on the Well Water Quality		71
4.11	Correlation Between Nitrate Level with Hazard Quotient		73
4.12	Health Risk Assessment		74
5	**CONCLUSION AND RECOMMENDATION FOR FUTURE RESEARCH**		
5.1	Introduction		77
5.2	Conclusion		77
5.3	Recommendation		78
5.4	Reflections on Research Experience		79

REFERENCES 80
APPENDICES 90
BIODATA OF STUDENT 101

LIST OF TABLES

Table		Page
1.1	Definition of Terms Used	8
2.1	Guideline Value for Chemicals from Agricultural Activities that are of Health Significance in Drinking Water	17
2.2	Guideline for Drinking Water for Known Concentration of Nitrate	17
4.1	Respondent's Background Information	51
4.2	Well Backgrounds of the Study	53
4.3	Nitrate Levels in Well Water during Different Planting Phase	65
4.4	Physicochemical Properties of Well Water in Kota Bharu	69
4.5	Physicochemical Properties of Well Water in Bachok	70
4.6	Correlation between Nitrate Levels and Water Parameters	70
4.7	Correlation between Nitrate Levels and Well Characteristics	71
4.8	Relationship between Nitrate Levels and Hazard Quotient	73
4.9	Weight, Daily Water Intake and Chronic Daily Intake of Respondents in Kota Bharu	74
4.10	Weight, Daily Water Intake and Chronic Daily Intake of Respondents in Bachok	74
4.11	Daily Water Intake of Respondents in Kota Bharu and Bachok	75
4.12	The Frequency of Hazard Quotient in Population in Kota Bharu and Bachok	75

LIST OF FIGURES

Figure		Page
1.1	Conceptual Framework of the Study	6
2.1	The Occurrence of Groundwater	10
2.2	Tube Well	12
2.3	Dug Well	12
2.4	Nitrogen Transformation in Soil That Produce Nitrate and Leach out to Groundwater	15
2.5	Pre-planting phase in Kelantan	19
2.6	Paddy field during planting phase in Kelantan	20
2.7	Paddy field during harvesting phase in Kelantan	21
2.8	Relationship between Environmental Factors and Cancer Incident	24
3.1	Map shows Kelantan state, Malaysia	29
3.2	Map shows Kota Bharu and Bachok, Kelantan	30
3.3	Rainfall amount in Malaysia, 2010	31
3.4	Land use map of Kelantan	33
3.5	The topography of Kelantan	34
3.6	The geology types in Kelantan	35
3.7	Water Treatment Plant which Include Groundwater Source in Kelantan	37
3.8	The Properties of Aquifer Layer in North Kelantan	38
3.9	Residential Area near Paddy Field in Kota Bharu	39
3.10	Villages Selected as Study Area	41
3.11	Map Shows the Sampling Point of Kota Bharu, Kelantan	43
3.12	Map Shows Sampling Point of Bachok, Kelantan	44
3.13	Example of Dug Well	45
3.14	YSI Professional Plus	46
4.1	Nitrate Level in Kota Bharu	56
4.2	Nitrate Level in Kota Bharu During Different Planting phase	57
4.3	Nitrate Level in Bachok	61
4.4	Nitrate Level in Bachok During Different Planting phase	62
4.5	The Comparison of Nitrate Levels in Kota Bharu (a) and Bachok (b) to the NDWQS Standars (10 mg/L)	68
4.6	Percentage of Respondents with Perceived Health Symptoms from the Ingestion of Well Water	72
4.7	Respondent's Satisfaction on Well Water Quality	72
4.8	Percentage of Well with Smelly and Cloudy Water	73

LIST OF ABBREVIATIONS

KADA	Kemubu Agricultural Department Authority
MOH	Ministry of Health
MOSTI	Ministry of Science, Technology and Innovation
NDWQS	National Drinking Water Quality Standard
HI	Hazard Index
CDI	Chronic Daily Intake
RfD	Reference Dose
WEPA	Water Environment Partnership in Asia
WHO	World Health Organization
USEPA	United Syayes Environmental Protection Agency
MOA	Ministry of Agriculture
IARC	International Agency for Research on Cancer
GIS	Geographical Information System

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter provides an overview of the subject that was researched. The problem that initiates the research, the study objectives and the rationale of doing the research was highlighted in this chapter. The chapter begins with an overview of nitrate in the environment, followed by the contamination of nitrate in groundwater and the effect of nitrate contamination to human health. The conceptual framework of the assessment and the scope of study were highlighted at the end of this chapter. This provides a basic knowledge of the issues assessed in this study.

Nitrate with molecular formula NO_3^- is an organic compound containing a nitrogen (N) atom combine with oxygen (O) atoms. Nitrate naturally occurs in the environment and drinking water and is part of nitrogen cycle (Toxfaqs, 2011). This organic matter commonly used in fertilizers products such as potassium nitrate and ammonium nitrate (Nishikiori, et al., 2012; Toxfaqs, 2011). Nitrate also can be found in low levels in vegetables and meat preservatives and as food additives (Milkowski et al., 2010; Santamaria, 2006).

Due to population growth and the increasing demand of food supply (Babiker, et al., 2004), high amount of nitrogen fertilizers are applied on crops to increase the yield (Koo & O'Connell, 2006). This had caused high contamination of nitrate on the soil, surface water and groundwater (Almasri & Kaluarachchi, 2007; Babiker et al., 2004; Bouman et al., 2002; Khademikia et al., 2013). According to Ismail, (2011) level of nitrate in groundwater was influenced by several factors such as rainfall. For example heavy rainfall cause rapid movements of fertilizers to groundwater thus increase the concentration. Nitrate contamination in groundwater also can occur from failing septic system (Khademikia et al., 2013). Bouman et al., (2002), had indicated the area near to agricultural sites may lead to high leaching rates of nitrate contamination to groundwater from fertilizers and pesticides application. The acceptable value nitrate in drinking water according to National Drinking Water Quality Standard (NDWQS) is 10 mg/l (MOH, 2013).

According to Mohamed Azwan et al., (2010), 70% of water supply in Kelantan is from groundwater and 40% of the population rely on groundwater for their daily purposes (Mahasim et al., 2005). Most of the land in Kelantan are used for paddy planting. About 45% of the land in Kelantan or 37,670 ha is used for paddy planting managed by Kemubu Agricultural Development Authority (KADA), Ministry of Agriculture and Agro-Based Industry Malaysia. KADA is responsible to increase the production of paddy and managed the plantation areas systematically (Abdul Manaff & Noriah, 2007) . The paddy planting in Kelantan is carried out in two seasons namely as off season (dry season) and main season (rainy season). Dry season usually begin in March to July while the rainy season begins in August to February. During dry season water supply is introduced from irrigation channel to the paddy farming area however, in rainy season the primary threat to paddy planting is flood and generally the planting reduced to 70%.

Exposure of high nitrate in humans may lead to various health problems such as methemolobinemia in infants and digestive tract cancer in adults and other diseases such as non-Hodgkin's' lymphoma, gastric cancer and inflammatory disease (Powlson et al., 2008). Since Kelantan is highly cultivated with paddy field, and majority of the population depends on groundwater for their water supply, it is important to monitor the level of nitrate in the groundwater and to assess the health risk of nitrate exposure to human particularly in the affected area.

1.2 Problem Statement

Nitrate is naturally occurring ions and it is essential in agriculture sustainability (Almasri, 2007; Capri et al., 2009). Nitrate also occurred from manmade activities. The sources of nitrate in environment includes fertilizer (Bouman et al., 2002; Gao et al., 2010; Kolpin, 1999), animals feedlots (Gelberg et al., 1999; Hargitt, 2001), septic tanks and waste landfills (Capri et al., 2009; Khademikia et al., 2013; Rao, 2006; Babiker, et al., 2004)

Nitrate is one of the elements that contaminate the groundwater. For example, nitrate was high in groundwater in Lebanon East-Mediterranean with the concentration of 200 mg/L (Darwish et al., 2011). Nitrate concentration in groundwater was influenced by several factors such as rainfall and temperature (Gao et al., 2012; Hargitt, 2001; Koo & O'Connell, 2006). There are few studies reported that nitrate level in groundwater was influenced by weather, for example wet and dry season (Bouman et al., 2002; Mahasim et al., 2005) . A study by Mahasim et al., (2005) reported that nitrate level is high during wet season because of precipitation that increase the leaching rate of nitrate into groundwater and heavy rainfall may influence the non-point sources of nitrate to leach out into groundwater. In contrast, nitrate level was low in dry season is likely because of no further factors that contribute to nitrate leaching. A study by Rao, (2006) stated that nitrate concentration in groundwater increase during pesticide and fertilizer application. During planting phase, high pesticide and fertilizers were applied to the land. This had caused nitrate to increase. In contrast, pesticide and fertilizer are not being applied during harvesting phase and cause the nitrate remain low in the groundwater.

Nitrate was found to cause several diseases. For instance, there is a significant positive association between nitrate in drinking water and gastric cancer mortality. Consumption of water or food contaminated with nitrate will affect human health and cause gastric cancer disease (Eichholzer & Gutzwiller, 1998; Sandor, et al., 2001; Tsugane & Sasazuki, 2007; Yang, et al., 1998). In Malaysia, gastric cancer is one of the common types of cancer. However, early detection is significant to improve the survival on gastric cancer patients (Kandasami et al., 2003). The incidence of gastric cancer cases in peninsular Malaysia was ranked as the seventh most common cancer among males and tenth among females (Zainal et al., 2006). Other diseases that was caused by nitrate exposure are non-Hodgkin's lymphoma and methemoglobinemia in infants (Azwan et al., 2010; Fewtrell, 2004).

Seventy percent (70%) of water supply in Kelantan is from groundwater and 40% of populations in North eastern districts in Kelantan rely on groundwater sources for their domestic and daily used (Mahasim et al., 2005). Jamaludin et al., (2013) had reported that nitrate level in Bachok, Kelantan was below the maximum contamination limit (MCL) of National Drinking Water Quality Standard (NDWQS). The nitrate

concentration was between 0 to 9.60 mg/L (Jamaludin et al., 2013).A study by Azwan et al., (2010) in Kota Bharu, Kelantan found that the maximum concentration of nitrate in his study is 17.16 mg/L which was exceeded the MCL value. Islami, et al., (2011) have reported that groundwater in Machang, Kelantan was contaminated by nitrate with the concentration above 20 mg/L.

Kelantan is one of the state located in north-east of Peninsular Malaysia with the area of 1509 kilometres square and 1.68 million (in 2013) (DOSM,2010). The main economy of this state is dominated by agriculture activity for example rice, tobacco and rubber. It has 10 districtsinclude Kota Bharu and Bachok. Kota Bharu is the main capital of Kelantan with 491, 237 (in 2013) of populations and 394 kilometres square of area. This major urban centre of Kelantan has 15 sub-districts with vast majority of the populations is ethnically Malay. The climate is tropical monsoon with average 2,600 mm of precipitation annually. Major economy activities in this district are business such as shopping activity, government employee, tourism and agriculture. Bachok is a local town located about 25 kilometres from Kota Bharu. The area consists of 280 kilometres square with the total population of 126,350 (in 2013). The major economy activity in this area is agriculture, fishing, business, government employee and private sector. Most of the population in these areas are depending on groundwater for their daily purpose. Majority of the land use in both areas are cultivated with paddy, tobacco, maize and Kenaf.

Heavy usage of pesticide and fertilizer on agriculture land has created a concern on the level of nitrate leach into groundwater. Nitrate can produce negative health impact to human(Nduka et al., 2009). In paddy planting area, the application of pesticide and fertilizer is high during planting phase and low during pre-planting and harvesting phase. High usage of pesticide and fertilizer during planting phase may cause nitrate to leach heavily into groundwater and create an exposure to the population.

Since groundwater is the major water supply among population in Kota Bharu and Bachok in Kelantan, they may expose to nitrate contamination in groundwater. This study was conducted for several manners in scope of the nitrate level in selected areas and the implication of nitrate exposure to the human health risk.

Kota Bharu and Bachok provide a good context for this study as both areas are paddy field cultivated sites which has high possibility to be contaminated with nitrate at three planting phases i.e. pre planting, planting and harvesting. Nitrate is being the main concern in this study because of the effects that it can produce to human health and environment. For example, high nitrate in environment may lead to environmental pollution and eutrophication problem (Gao & Zhang, 2010, Koo & O'Connell, 2006) while high exposure to nitrate by human can cause several chronic diseases such as non-hodgkins' lymphoma, thyroidal dysfunction, methemoglobinemia and gastric cancer. In short term exposure, nitrate can cause nausea, fever, dizziness and lowering blood pressure (Hobbs et al., 2013).

At present, limited research was done on the level of nitrate during three paddy planting phases. The health risk of the population who used groundwater frequently in agriculture sites in Kelantan also was not well presented. This factor has encouraged this study to be conducted with an aim to determine the level of nitrate in the groundwater and to measure the risk of nitrate exposure to the affected respondents.

1.3 Objectives of Study

The general objective of this study was to determine nitrate level in well water and population health risk of Kota Bharu and Bachok, Kelantan in different planting phases

While, the specific objectives are as below:

i. To determine the socio-demographics of respondents and well characteristics in the study area.

ii. To compare the nitrate levels of the well water between two study areas during three planting phases.

iii. To compare the nitrate levels in well water of Kota Bharu and Bachok in three paddy planting phases to the National Drinking Water Quality Standard.

iv. To determine the relationship between nitrate levels and physico chemical properties of the well water (such as water pH, temperature and pressure) and well characteristics.

v. To determine the perceived health symptoms and health risk of population in study areas from the nitrate exposure.

1.4 Hypothesis

i. There is significant difference between nitrates levels and physico-chemical properties of the well water in the study area during three planting phases (pre planting, planting and harvesting phase).

ii. The nitrate levels in well water of Kota Bharu and Bachok in three paddy planting phase are within the acceptable limit of the National Drinking Water Quality Standard

iii. There is significant relationship between nitrate level with the physico chemical properties and the well characteristics.

iv. The perceived health symptoms and health risk of the population in Kota Bharu and Bachok is within an acceptable limit.

1.5 Conceptual Framework

Figure 1.1 shows the conceptual framework of this study which aim to determine the nitrate levels in well water and the health risk among the population in Kelantan. This study was conducted among residents in Kota Bharu and Bachok districts who used unfiltered well water for daily usage.

Nitrate from various sources such as organic and organic fertilizers that used on crop for example paddy field were leach into groundwater. The concentration of nitrate in groundwater may be different through different planting phase which are pre-planting, planting and harvesting phase. Therefore, this study monitored the level of nitrate in different planting phases. Other factors that influence nitrate concentration are physical characteristics of well water such as water temperature, pressure and pH and well characteristics which include well age, distance from agriculture area, maintenance and

depth – were also measured in this study. The wells were selected based on inclusive and exclusive criteria and the respondents were from the owner of the wells and their family members that fulfil the selection criteria.

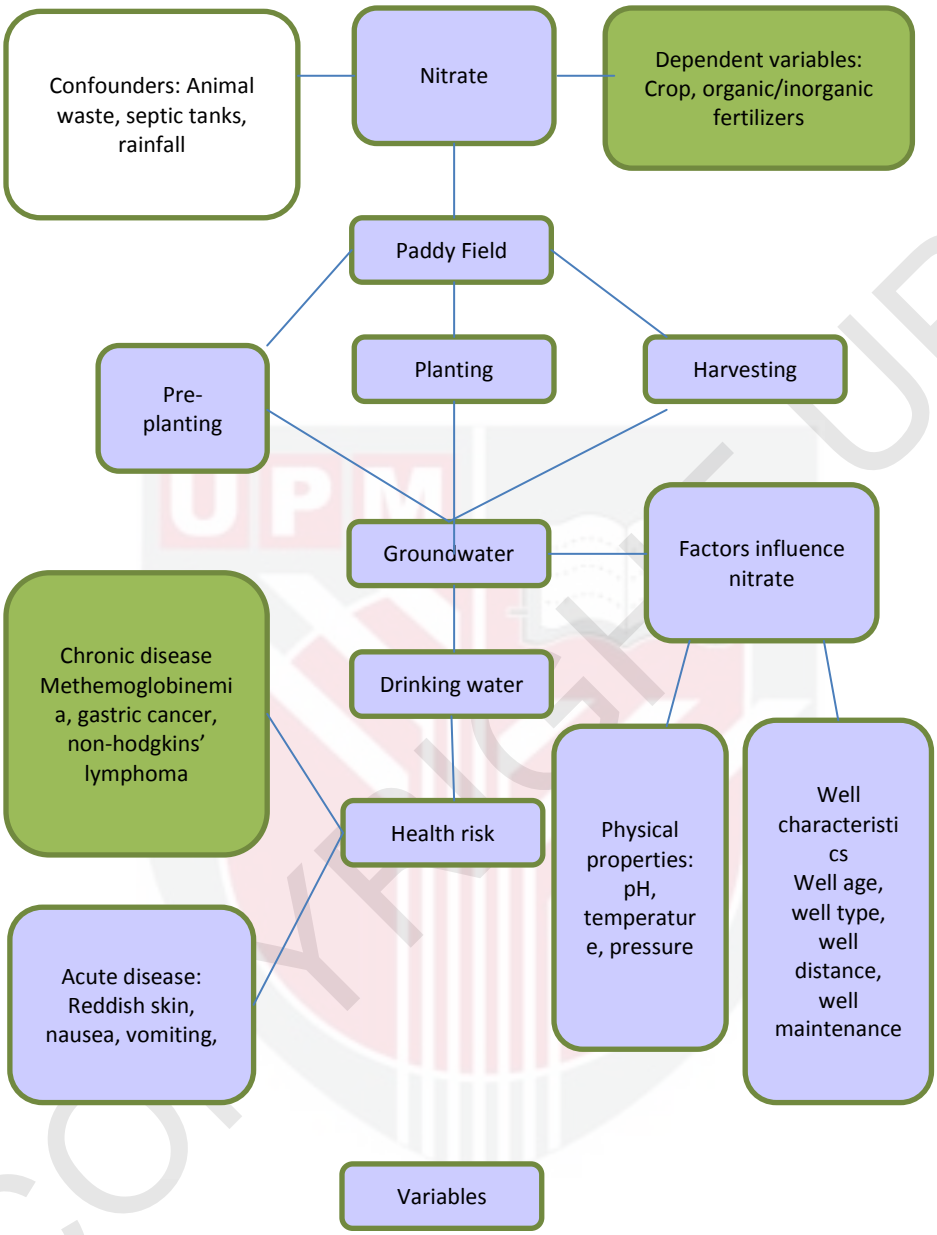

Figure 1.1: Conceptual framework of the study

1.6 Scope of Study

The scope of this study is the nitrate levels in the well water. Well which is located within 100 meter from the paddy planting areas in Kota Bharu and Bachok are the focus on this study. Nitrate concentration in well water during pre-planting, planting and harvesting phase are measured in this study. A study also associates the related health symptom of respondents with the nitrate level and calculates the health risks of residents using the scientific formula

.

1.7 Significant of the study

This study is significant as from various literatures various health effects were reported from the effect of nitrate contamination in groundwater especially gastric cancer and methemoglobinemia. The occurrence of this disease may lead to death. Therefore, nitrate monitoring in well water need to be conducted to prevent level of expose to human that can cause negative health effects.

Furthermore, rural area in Kota Bharu and Bachok Kelantan were the focus in this study as they have number of residents use well water as their main drinking water source and the groundwater source were at risk of nitrate pollution. Nitrate in the groundwater source from the agriculture activity in the area. This study assessed the difference of nitrate concentration in different planting phases and to determine the association between nitrate concentration and the physico-chemical characteristics of the well water in this area. This is very important to determine the cause effect relationship between the nitrate concentration and the health effects.

This study contributes to the knowledge of nitrate contamination in the groundwater and the side effects from the exposure.

1.8 Terms Definition

Table 1.2 shows the definition of terms that used in this study which are includes the medical terms and geological terms.**Table 1.1: Definition of terms used.**

Terms Used	Definition
Chronic daily intake	Exposure expressed as mass of a substance contacted per unit body weight per unit time.
Diagnosis	The process of attempting to determine or identify a possible disease or disorder.
Drinking water	Water used for domestic purposes, drinking, cooking and personal hygiene.
Gastric cancer	Gastric cancer or stomach cancer refers to cancer arising from any part of the stomach. It is a disease in which the cells forming the inner lining of the stomach become abnormal and start to divide uncontrollably, forming a mass called a tumor.
Ground water	Water occurring, underground, in the zone of saturation in an aquifer.
Hazard index (HI)	The sum of more than one hazard quotient for multiple substances and/or multiple exposure pathways. The HI is calculated separately for chronic, sub chronic, and shorter-duration exposure.
Health risk assessment	Qualitative and quantitative evaluation of the risk posed to human health by the actual or potential presence of specific contaminants.
National standard	A standard adopted by a national standardization body and made available to the public
Nitrate	A salt or ester of nitric acid, containing the anion NO_3^- or the group $-NO_3^-$
Reference dose (RfD)	The Agency's preferred toxicity value for evaluating non-carcinogenic effects result from exposures at Superfund sites.

Source: (Gerba, 2006; WHO, 2008)

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