UNIVERSITI PUTRA MALAYSIA

HEALTH RISK ASSESSMENT OF RESIDUAL ALUMINIUM IN DRINKING WATER AMONG SETTLERS OF FELDA PALONG 4,5,6,7 AND 8,NEGERI SEMBILAN

BY
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ABSTRACT

HEALTH RISK ASSESSMENT OF RESIDUL ALUMINIUM IN DRINKING WATER AMONG SETTLERS OF FELDA PALONG 4,5,6,7 AND 8, NEGERI SEMBILAN

RAHIMAH SAPAI

Introduction: A cross-sectional study was conducted in Felda Palong, Negeri Sembilan. **Objective:** The main objective in this study was to determine health risk of exposure to aluminium levels in drinking water at Felda Palong, Negeri Sembilan. **Method:** A total of 60 respondents were selected to participate in this study. Two water samples were taken from each respondent's house, and then, was preserved using 0.5 ml of concentrated nitric acid (69%) and analysed using Graphite Furnace Atomic Absorption Spectrometer (GFAAS). Water pH level was measured by using a Lamotte Tracer Orp Pocketester. Besides that, body weight of respondent's also been measured by using a Seca Body Weight Scale. The interviewed session also had been done in order to know the respondents daily water intake, socio-demographic background and status of water quality supply. The health risk was calculated for each respondent using equation of Chronic Daily Intake and Hazard Index based on the information given by respondents. **Results:** Results showed that 53% of water samples exceeded the upper safe limit of National Standard for Drinking Water Quality Malaysia (>0.2mg/L). The value of mean (SD) for aluminium levels in water samples was 0.292 (0.217) mg/L. The value of mean (SD) for pH level in water samples was 6.865 (0.429). There were significance difference between aluminium level and Malaysian Drinking Water Quality Standard with ($z = 0.02$, $p<0.001$). Pearson Correlation test showed that was significant relationship between aluminium levels in water samples and pH level. Hazard Index (HI) calculation showed that all respondents had "HI" of less than 1. **Conclusion:** The calculation of health risk of aluminium exposure in drinking water found that the risk was in acceptable level.

Keywords: Aluminium, drinking water, health risk assessment, hazard index (HI), pH Level, Felda Palong

ABSTRAK

KAJIAN RISIKO KESIHATAN TERHADAP BAKI ALUMINIUM DIDALAM AIR MINUM DIKALANGAN PENDUDUK KAWASAN FELDA PALONG 4,5,6,7 DAN 8, NEGERI SEMBILAN

RAHIMAH SAPAI

Pendahuluan: Kajian keratan rentas ini telah dijalankan di Felda Palong, Negeri Sembilan. **Objektif:** Objektif utama kajian ini adalah untuk mengenalpasti kajian risiko kesihatan terhadap paras aluminium dalam air minum di kawasan Felda Palong, Negeri Sembilan. **Methodologi:** Seramai 60 orang responden telah dipilih untuk menyertai kajian ini. Sampel air telah diambil sebanyak dua sampel untuk setiap rumah responden. Selepas itu, sampel air diawet menggunakan 0.5 mL asid nitrik pekat (69%) dan dianalisis menggunakan alat GFAAS. Nilai pH diukur menggunakan alat Lamotte Tracer Orp Pocketester. Di samping itu,berat responden turut ditimbang menggunakan penimbang berat Seca. Sesi soal jawab diadakan dan beberapa soalan turut diajukan kepada responden berkaitan dengan latar belakang responden, kadar air minum dalam sehari dan status kualiti air yang dibekalkan ke rumah. Risiko kesihatan setiap responden dikira menggunakan rumus pengambilan harian kronik dan indeks risiko dengan berdasarkan maklumat yang telah diperolehi. **Keputusan:** Hasil daripada kajian menunjukkan sebanyak 53% sampel air melebihi piawaian paras aluminium didalam air minum (> 0.2 mg/L). Nilai min (SP) bagi paras aluminium dalam sampel air ialah 0.292 (0.217) mg/L. Nilai min (SP) bagi paras pH dalam sampel air ialah 6.865 (0.429).Terdapat perbezaan di antara paras aluminium dan piawai kualiti air minum($z = 0.02$, $p<0.001$). Ujian hubung kait Pearson menunjukan ada hubung kait antara paras aluminium dan nilai pH dalam sampel air. Pengiraan risiko kesihatan menunjukkan semua responden mempunyai risiko kurang dari 1. **Kesimpulan:** Pengiraan risiko kesihatan terhadap pendedahan aluminium di dalam air minum menunjukkan risiko kesihatan responden adalah diterima.

Kata kunci: Aluminium, air minum, kajian risiko kesihatan, risiko kesihatan, nilai pH, Felda Palong

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Al	Aluminium
AD	Alzheimer's Disease
ADWG	Australian Drinking Water Guidelines
ATSDR	Agency for Toxic Substances and Disease Registry
CEPA	California Environmental Protection Agency
FELDA	Federal Land Development Authority
JPM	Jabatan Perangkaan Malaysia
$\mu g/m^3$	microgram per metre cubic
mg/L	milligram per litre
NSDWQ	National Standard for Drinking water Quality
PNHSB	Puncak Niaga Holding Sdn. Bhd
RfD	Reference Dose
USEPA	United States Environmental Protection Agency
WHO	World Health Organization

CHAPTER 1

INTRODUCTION

1.1 Introduction

1.1.1 Aluminium

Aluminium (Al) is the most abundant metallic element and the third most abundant element, after oxygen and silicon (Agency for Toxic Substances and Disease Registry, 2006) predominantly as oxides and alumina silicates (Pesavento et al., 1998). It constitutes of 8% Earth's crust (World Health Organization, 1998). Al as metal is obtained from Al containing minerals, primarily bauxite. Al metal is light in weight and silvery-white in appearance (ATSDR, 2008).

Al occurs naturally in the environment as silicates, oxides, and hydroxides. It can combine with other elements, such as sodium and fluoride. The combination of Al with organic matter can produce Al complexes (ATSDR, 2006; WHO, 1998).

1.1.2 Sources of Aluminium

There are three main sources of Al which are; environment, occupational exposure and consumer products. Al in environment is widely distributed in most rocks, soils, waters, air, and foods. Human always has some exposure to low levels of Al from food, drinking water, and also air (ATSDR, 2006).

The exposure of Al from occupational industries can be high by range from 0.4 to 8.0 μg/ m^3. The amount of Al that human breathes in a day is much less than being consume in food. Human may breathe in high levels of Al in dust if they live in areas where the air is dusty, where Al is mined or processed into Al metal, or near certain hazardous waste site (ATSDR, 2008).

Al in consumer product generally exist in a form of salts, added to a range of commercially-prepared foods and beverages, to clarify drinking water, make salt free-pouring, colour snack or dessert foods, and make baked goods rise (Walton, 2006). According to World Health Organization (WHO, 2012), oral ingestion of Al is the main form of Al exposure to the general public.

According to the World Health Organization, the International Water Quality Standards (IWQS) of Al level is 0.2 mg/L (Walton, 2006). Al is classified in Group II inorganic metal according to National Standard for Drinking Water Quality (NSDWQ) prepared by Ministry of Health Malaysia. The upper safe limit of Al level in drinking water is 0.2 mg/L (Ministry of Health, 2004).

1.1.3 Aluminium in Drinking Water

Safe drinking water is an essential need for human well-being, health, development and basic necessity. For example, 162 litres of drinking water is consumed on average per person a day in private households in Switzerland (Jungbluth, 2006) and it is internationally recognized as fundamental human rights.

Al is one of the trace inorganic metals present in drinking water (Srinivasan et al., 1999). There are two main sources of Al in drinking water. Firstly, Al exist naturally as a result of leaching from minerals in the soil and bedrock in the catchment of the water source (Srinivasan et al., 1999). Secondly, Al is widely used as coagulant in water treatment, to reduce the number of small particles and to improve the colour of the water via coagulation process (Flaten, 2001; Srinivasan et al., 1999; Nasir et al., 2010).

Farizwana et al. (2010) indicated that Al levels in treated water were higher than Al levels at water source based on study at Johor, Malaysia. This is due to the excessive amount of Al sulphate added during the water treatment process. The addition of Al sulphate was done only by observing the water turbidity, not according to the correct calculated required amount of alum before they were released to the resident's tap waters.

High level of Al (3.6 to 6 mg/l) can precipitate as Al hydroxide in water resulted from water treatment process in Canada (Srinivasan et al., 1999). However, if treatment process is functioning optimally, the addition of Al may actually result in lower Al level in the treated water than in the raw water (Flaten, 2001).

According to Australian Drinking Water Guidelines (ADWG) (ADWG, 2001), a well-operated water filtration plant (even using Al as a flocculants) can achieve Al levels in the finished water of less than 0.1 mg/L. In addition, the residual Al level in treated water is depend on the level in water source, the Al sulphate dose used, the pH and the filtration efficiency.

1.1.4 Effect of Aluminium Exposure to Human Health

Al is a strong element that considered as a subtle promoter of events typically associated with brain aging (Bondy, 2010). In Alzheimer's disease (AD) there is progressive decrease in brain mass with the accumulation of phospholipid-rich cell debris. These membrane tangles in brain tend to accumulate Al (Caster and Wang, 1981).

Al might be implicated in the pathogenesis of the disease. The elemental composition of the two types of brain lesions which characterize AD has been the subject of intense scrutiny over the last decade, ever since it was proposed that inorganic trace elements (Makjanic and Watt, 1999).

In addition, exposures to Al also contribute in dialysis dementia, Parkinson and AD (Nasir et al., 2010). Al is also a suspected causative agent of neurological disorders such as AD and presenile dementia in Canada (Srinivasan et al., 1999). Martyn et al. (1997) indicated there was little association between AD and higher Al levels in drinking water when cases were compared with any of the control groups. Exposure to Al in drinking water was estimated from residential histories of 106 men with Alzheimer's disease, 99 men with other dementing illnesses, 226 men with brain cancer, and 441 men with other diseases of the nervous system.

Furthermore, acute exposure to Al can cause clinical neurotoxicity (Bondy, 2010). Elevated levels of intrinsic inflammation are associated with neural aging and this is exacerbated in several neurodegenerative diseases. Toxicity of Al also can result in aching muscles, speech problems, anaemia, digestive problems, lowered liver function and impaired kidney function. In addition, Al can poisonous to the nervous system with a range of symptoms that can include disturbed sleep, nervousness, emotional instability, memory loss, headaches, and impaired intellect (Pepi, 2012).

1.2 Problem Statement

Al compounds such as Al sulphate (alum) are commonly used in water treatment as coagulate factor to enhance the removal of particulate, colloidal and dissolved substances via coagulation processes (Srinivasan et al., 1999). Al salt such polyaluminium chloride (PACl) are used extensively as coagulants in drinking water treatment (Rubinos, 2005).

The use of alum as a coagulant for water treatment often leads to high levels of Al in treated water (drinking water) than in raw water (Srinivasan et al., 1999). Al-based coagulants have come under scrutiny in recent years due to concerns about metal residuals in the public water supply (Rubinos, 2005).

Al can cause AD, dementia and Parkinson disease. There have been a number of epidemiological studies to determine the relationship of Al in drinking water to Alzheimer's disease. Epidemiological studies have suggested a link between an increase in the incidence of AD in regions where the levels of Al in drinking water are high (Forbes and McLachlan, 1996; Rondeau et al., 2000).

AD is a chronic condition that is characterised by progressive loss of memory and other brain functions of daily living. Relevant exposure levels of concern for the general population identified as part of dose response assessment include neurological effects due to drinking water exposure (0.1 mg/L) (Krewski et al., 2009).

Dementia is a clinical condition in which the individual experiences a loss of cognitive function severe enough to interfere with normal daily activities and social relationships (Traywick, 2007). Dialysis dementia is encephalopathy when kidney dialysis patients, in whom the gut barrier is bypassed, can accumulate Al in their blood.

Parkinson disease is characterized by bradykinesia (slowed ability to start and continue movements), resting tremor and postural instability (Kruger, 2003). Perl and Brody (1980) stated elevated levels of Al have been found in the autopsied brains of people who had suffered AD, in region of the brain containing large numbers of the neurofibrillary tangles which are characteristic of the disease and Al has been proposed as one of a number of causal agents.

Al in drinking water was considered to be one of the main sources of Al intake into human body (Nasir et al., 2010). An average adult intake of Al level from drinking water is 0.1 mg/L. High level of Al in drinking water may cause dementia, Parkinson and AD (Mohammad et al., 2011). Al level in drinking water generally in acceptable ranges according to the European Union standards, however, some reports suggested that the presence of Al can cause toxic effects even it occur in small quantities (Kawther and Alwakeel, 2007).

At present, there are limited studies done to investigate this issue. Although water is reliable and safe in terms of quantity and quality in Malaysia, but there are violations of water quality standard especially Al in Negeri Sembilan from 2006 until 2008 (Jabatan Audit Negara Malaysia, 2008). Therefore, this study was performed to determine the levels of Al in drinking water and to assess the health risk of Felda settler's exposed to Al in Felda Palong, Negeri Sembilan.

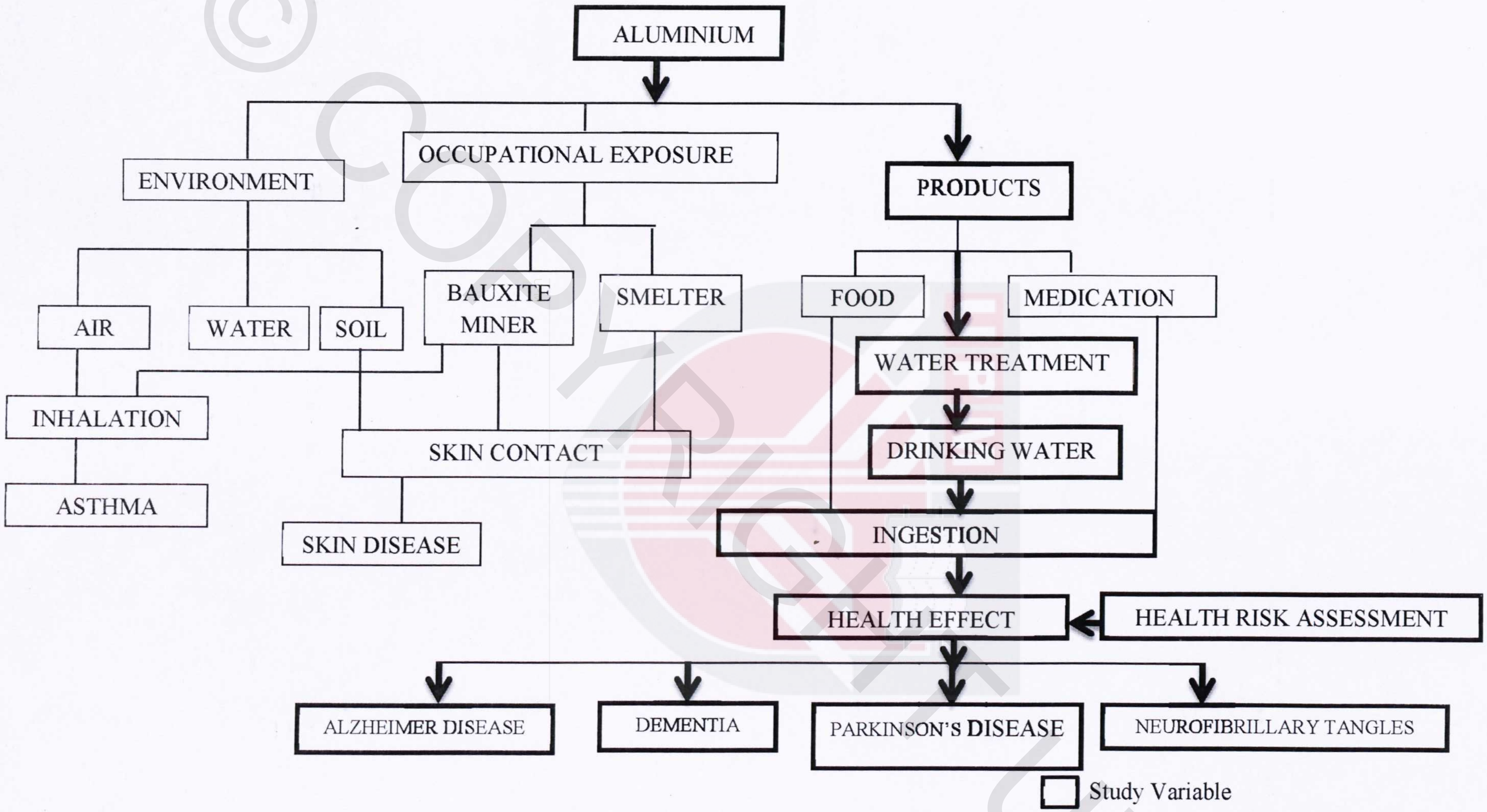
1.3 Study Justification

This study was a medium to increase health awareness among Felda Settlers' with regards to the water quality. Study was done to monitor water quality and appropriate mitigation measures can be taken based on finding. The water treatment systems in the country is using a conventional system; putting Al sulphate in water treatment processes manually by an operator. They have the potential to put a high volume of Al sulphate to purify water in the water treatment plant that can increase Al level to above than standard of water quality.

Study was conducted at Felda Palong, Negeri Sembilan; a rural area. Limited data is available to determine the risk associated with Al exposure in drinking water in Malaysia (Dzulfakar et al., 2011) especially among Felda (Federal Land Development Authority) settlers. Felda is the rural area that was developed as an agricultural area and has a positive impact on the economy development of the country. Meanwhile, there are significant numbers of population currently living in Felda and this area is potential to be developed in the future. Thus, the quality of water supply needs to be assessed.

1.4 Conceptual Framework

The sources of the exposure to aluminium come from exposure to environment, occupational exposure and products. The exposure of aluminium in drinking water comes from water treatment plant that added alum for coagulation and flocculation process. The drinking water that ingested can cause health effect to human such as Alzheimer's disease, dementia, Parkinson disease and neurofibrillary tangles. Health risk assessment has been done to assess the health risk of Al exposure to human.


ALUMINIUM
ENVIRONMENT
OCCUPATIONAL EXPOSURE
PRODUCTS
AIR
WATER
SOIL
BAUXITE MINER
SMELTER
FOOD
MEDICATION
WATER TREATMENT
DRINKING WATER
INHALATION
SKIN CONTACT
ASTHMA
SKIN DISEASE
INGESTION
HEALTH EFFECT
HEALTH RISK ASSESSMENT
ALZHEIMER DISEASE
DEMENTIA
PARKINSON'S DISEASE
NEUROFIBRILLARY TANGLES
Study Variable

1.5 Definition

1.5.1 Conceptual Definition

1.5.1.1 Settlers

Settler is referring to a person who maintains residency (domicile) for 6 month in a given place (Jabatan Perangkaan Malaysia, 2011).

1.5.1.2 Drinking water

Drinking water or potable water is water of sufficiently high quality that can be consumed or used with low risk of immediate or long term harm.

1.5.1.3 Aluminium level

Al level is the level of Al in the drinking water (Krewski et al., 2009). The upper safe limit of Al level in drinking water is 0.2 mg/L (MOH, 2004).

1.5.1.4 Hazard index

A summation of the hazard quotients for all chemicals to individual is exposed. A hazard index value of 1 or less than 1 indicates that no adverse human health effects (no cancer) are expected to occur.

1.5.1.5 Health risk assessment

Health risk assessment is an assessment tool or questionnaire scientifically designed to identify health risks and outline information to assist person in making healthful changes that impact their health. The risk assessment process is typically described as consisting four basic steps: hazard identification, exposure assessment, dose response assessment and risk characterization (United States Environmental Protection Agency, 2010).

1.5.2 Operational Definition

1.5.2.1 Settlers

Settler is referring to a person who maintains residency (domicile) for 6 month in a given place (JPM, 2011).

1.5.2.2 Drinking water

Drinking water or potable water is water of sufficiently high quality that can be consumed or used with low risk of immediate or long term harm.

1.5.2.3 Aluminium level

Al in drinking water is measured by analysing Al level from samples collected from residential tap water. The water samples are analyses by using Perkin Elmer Graphite Furnace Atomic Absorption Spectrometer (GFAAS). Each sample result will be compare with NSDWQ which is cannot exceed upper safe limit of 0.2 mg/L for Al.

1.5.2.4 Hazard index

The hazard index is calculated by dividing the dose received as a result of some exposure scenario by the reference dose for a chemical:

$$HI = \frac{\text{Chronic daily intake (CDI)}}{\text{Reference Dose (RfD)}}$$

RfD for Al is 7 mg/kg/day (FAO and WHO, 1989). If the HI is greater than 1, an individual is at some risk of adverse health effects, because their dose exceeds a regulatory agency's estimate of the allowable daily intake.

15.2.5 Health risk assessment

According USEPA (2010), to estimated daily exposure of individuals for Al exposure through ingestion is by calculating CDI as the exposure metric. Then, to estimate the non-carcinogenic risk of Al the hazard index (HI) is calculated using the equation.

1.6 Research Objectives

1.6.1 General objective

To determine health risk assessment of exposure to residual Al in drinking water at Felda Palong 4,5,6,7 and 8, Negeri Sembilan.

1.6.2 Specific objectives

1. To determine the socio-demographic data of respondents at Felda Palong 4,5,6,7 and 8, Negeri Sembilan.
2. To determine Al and pH levels in drinking water at Felda Palong 4,5,6,7 and 8, Negeri Sembilan.
3. To determine the distribution of Al levels in Felda Palong 4,5,6,7 and 8, Negeri Sembilan by using Geographical Information System
4. To compare Al levels at Felda Palong 4,5,6,7 and 8, Negeri Sembilan with National Standard for Drinking Water Quality.
5. To determine the relationship of Al in drinking water and pH level.
6. To determine Hazard Index (HI) of Al intake for respondents at Felda Palong 4,5,6,7 and 8, Felda Palong, Negeri Sembilan.

1.6.3 Hypotheses

1. There are significant differences of Al levels at Felda Palong 4,5,6,7 and 8, Negeri Sembilan compare with National Standard for Drinking Water Quality (NSDWQ).
2. There is significant relationship of Al and pH level in drinking water at Felda Palong 4, 5, 6, 7 and 8, Negeri Sembilan.

CHAPTER 2

LITERATURE REVIEW

2.1 Aluminium

2.1.1 History

The most important aluminous ore for the manufacture of Al is bauxite. It consists of several hydrous Al oxide phases such as gibbsite $Al(OH_3)$, boehmite (AlOOH) and diaspora ($Al_2O_3H_2O$). Bauxite contains 40-60 per cent alumina (Al_2O_3) combine with small amounts of silicon, iron and titanium compounds as well as other trace impurities, nearly all of which appear in commercial Al (Burkin, 1987) .

High quality bauxite deposits are found in Australia, Brazil, Guinea, Jamaica and other tropical and semitropical areas where selective leaching has produced alumina levels (Burkin, 1987) . Pure alumina was first prepared from alum by Pott in 1976. Karl Joseph Bayer patented an improved process for making pure alumina from bauxite and from that time bauxite-type materials have been the preferred ores for Al production (Burkin, 1987).

2.1.2 Physicochemical Properties

Al is a silver-like metal with a slightly bluish tint. It has a melting point of 660°C (1,220°F) and a boiling point of 2,327-2,450°C (4,221-4,442°F). The density of Al is 2.708 grams per cubic centimetre. Al is both ductile (capable of being pulled into thin wires) and malleable (capable of being hammered into thin sheets). Al is also an excellent conductor of electricity (California Environmental Protection Agency, 2011). Al is an active metal. It reacts with many hot acids and alkalis. Al also reacts quickly with hot water. In powdered form, it catches fire quickly when exposed to a flame (CEPA, 2011).

2.1.3 Major Uses

Al is widely used in water treatment as a coagulant (Flaten, 2001) for purification of drinking water and as food additives (Bondy, 2010). Al also use as one element in antacids. Al-based antacids have generally been recommended for ulcer patients as they have a longer duration of action than other antacid types (Flaten, 2001). Al hydroxide is used as an antacid that can prevent the phosphatemia seen in severe kidney damage (Caster and Wang, 1981).

In addition, Al salts are added to a range of commercially-prepared foods and beverages: to clarify drinking water, make salt free-pouring, colour snack or dessert foods, and make baked goods rise (Walton, 2006). Other than that, Al is commonly found in deodorants as it is easily absorbed through the skin and effectively blocks the sweat pores (Tharmakulanathan, 2004).

2.2 Source of Aluminium in Environment

2.2.1 Natural Sources

Al is the most abundant metal and the third most abundant element, after oxygen and silicon, in the earth's crust. It is widely distributed and constitutes approximately 8.8% of the earth's crust (ATSDR, 2006; WHO, 1998).

It occurs naturally in the environment as silicates, oxides, and hydroxides, combined with other elements, such as sodium and fluoride, and as complexes with organic matter (WHO, 1998). Al occurs naturally in soil, water, and air (ATSDR, 2008). The average Al level in air is 0.005–0.18 $\mu g/m^3$ in urban area and 0.4–8.0 $\mu g/m^3$ in industrial areas. The Al level in soil varies widely ranging from 7 to over 100 g/kg while in surface water is generally below 0.1 mg/L (ATSDR, 2009). Al is normally present in raw water. The levels are usually low in ground waters and are almost always high in surface waters. Acid rain markedly increases the Al content of water. The geological factors include the nature of the bedrock, with regard to both basic minerals and acid-soluble toxic metals, together with the depth, texture, mineral and organic content of the overlying soil also the source of Al in environment (Wills and Savory, 1985).

2.2.2 Anthropogenic Sources

Mining activities and processing of Al ores or the production of Al metal, alloys, and compounds are the major Al producer in environment. Small amounts of Al are released into the environment from coal-fired power plants and incinerators (ATSDR, 2008).

Al cannot be destroyed in the environment but can change its form or become attached or separated from particles. Al particles in air settle to the ground or are washed out of the air by rain. However, very small Al particles can stay in the air for many days. Most Al-containing compounds do not dissolve to a large extent in water unless the water is acidic or very alkaline (ATSDR, 2008). Some domestic tap water contains Al in high level because Al has been added as a flocculants in the purification process. Al salts are used as a flocculants to remove organic materials present in surface water that might affect either colour or taste. Al sulphate is the commonly used flocculants (Wills and Savory, 1985).

2.3 Exposure to Aluminium

Al compounds are used in many diverse and important industrial applications such as Al sulphate (alums) in water treatment. They are found in consumer products such as antacids, astringents, buffered aspirin, food additives, and antiperspirants. Powdered Al metal is often used in explosives and fireworks (ATSDR, 2006). The route of Al exposure to human is through ingestion, direct contact and inhalation (ATSDR, 2008).

Al intake via oral route (ingestion) is range up to 90 mg/day. Al in medicines may increase exposure among human (Greim & Snyder, 2008). When considering bioavailability, namely the fraction that is actually taken up into the blood stream, food is again the primary uptake source for individuals whom not occupationally exposed. However, chronic use of antacids, buffered aspirins and other medical preparations would likely constitute the major uptake source (ATSDR, 2009; Krewski et al., 2009), followed by drinking water (Krewski et al., 2009).

Significant amounts of Al may also be supplied from Al cooking utensils, although this exposure has attracted less attention (Rondeau et al., 2000). Other water parameters such as pH, turbidity and level of calcium, silicon, fluoride and dissolved organic matter (DOM) influenced the solubility behaviour and the absorption of Al in the gastrointestinal tract (Rubinos, 2005).

It also can be exposed to skin through soil, water, Al metal, antiperspirants, or other substances that contain Al or Al compounds. Many of the analytical methods used by scientists to determine the levels of Al in the environment generally do not determine the specific form of Al present and only determine the total amount of Al present in the sample (ATSDR, 2006). Exposure of Al by dermal contact can happen when human skins come into contact with Al (ATSDR, 2008).

ATSDR (2009) stated occupational worker has potential for exposure during the refining of the primary metal and in secondary industries that fabricate Al products (such as aircraft, automotive, and metal products) and Al welding. Occupational exposure to Al occurs during the refining of the primary metal and in secondary industries that use Al products (Krewski et al., 2009).

Workers in refineries or smelters can be exposed to Al in the form of dusts, fumes or skin contact (Rondeau et al., 2000). Benke et al. (1998) reviewed the different specific chemical exposures and exposure assessment methods relating to epidemiological studies in the Al industry. Workers in the Al production and user industries experience considerable exposures to the metal or its compounds (Krewski et al., 2009).

2.4 Aluminium in Drinking Water

Al in drinking water is considered to be one of the main sources of Al intake into human body (Nasir et al., 2010). Al is used for removal of orthophosphate or dissolved organic matter in drinking water (Georgantas and Grigoropoulou, 2006). There are two Al sources such as Al sulphate [$Al_2(SO_4)^3 \cdot 18H_2O$] and Al hydroxide [$Al(OH)^3(s)$] in the removal process.

2.4.1 Water Treatment Plant

The most common process for surface water supplies is conventional water treatment, which consists of disinfection, coagulations, flocculation, sedimentation (the gravitational settling of heavier particle) and filtration followed by a secondary disinfection step as shown in Figure 2.1

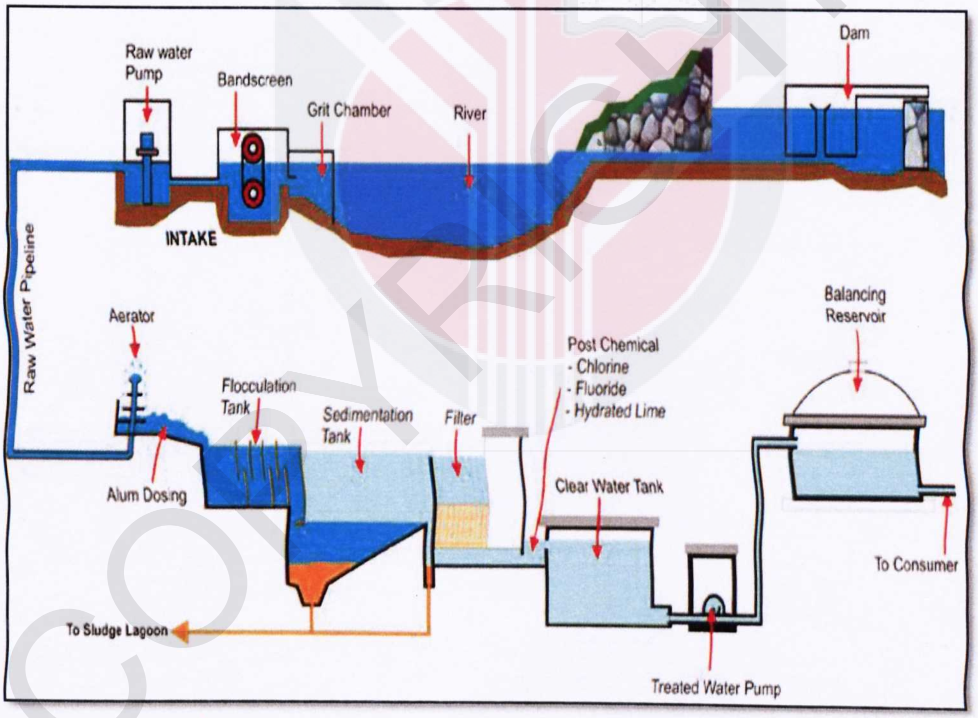


Figure 2.1: Water Treatment Process (Puncak Niaga Holding Sdn. Bhd., 2012)

In coagulation and flocculation process, chemical coagulants (usually Al sulphate) added to react with the remaining small particles in the water to form particles large enough to settle out. Rapid mixing distributes the coagulant evenly throughout the water (PNHSB, 2012). Previous research has reported that pH of drinking water influenced the solubility of Al components and the type of Al containing species that are formed in water. Besides, biological availability of Al is reported as higher in low pH (acidic) compared to high pH (alkaline), which correlates the pH level and Al level (Rondeau et al., 2000).

Al is soluble at acidic (pH <6) and alkaline (pH >6) conditions, but is insoluble at near neutral pH values (7.0 to 7.5) (Rubinos, 2005). Hrudey and Hrudey (2004) also indicated in the range of 5.8 to 8.5 and sufficient alkalinity Al sulphate will be available in water, otherwise, it will not react completely and no effective coagulation is achieved. In addition, the minimum solubility of Al usually lies within this range (pH 6.0 – 7.0), which is important to consider during the control of Al residuals (Dorea, 2008). Al can hydrolyse and precipitate more effectively and over wider pH ranges to produce satisfactory water quality as well as maintaining low residual Al levels (Simpson et al., 2008). In addition, temperature and turbidity also important factors in determining Al solubility and consequently residual Al (Srinivasan et al., 1999).

2.4.2 Drinking Water Guidelines Standard

According to National Standard for Drinking Water Quality (NSDWQ), the upper safe limit for Al level is 0.2 mg/L (MOH, 2004). World Health Organisation (WHO) also proposed a guideline value for Al in drinking water is 0.2 mg/L. This value is providing a compromise between the use of Al salts in water treatment and discoloration (due to Al $(OH)^3$ flocculation) of distributed water (Srinivisan et al., 1999).

Environment Protection Agency (EPA) establishes secondary maximum contaminant level (SMCLs) for drinking water contaminants for Al as 0.05 to 0.2 mg/L. SMCLs are not enforceable, but some may adopted as regulations by individual states (Howd and Fan, 2008).

2.5 Health Effects

There are numerous studies that have examined Al's potential to induce toxic effects in humans exposed via inhalation, oral, or dermal exposure. Most of these findings are supported by a large number of studies in animals (Howd and Fan, 2008).

2.5.1 Alzheimer's Disease

A neurological effect that has been proposed to be associated with Al exposure is Alzheimer's disease (AD) (Nasir et al., 2010). In other study, among potential environmental risk factors for AD, Al has been the most intensively studied neurotoxic substance (Gauthier et al., 2000. Roundeau et al. (2000) also has supported the hypothesis that high level of Al in drinking water may be a risk factor for AD. AD is a chronic condition that is characterised by progressive loss of memory and other brain functions of daily living. Al salts in drinking water can increase levels of glial activation, inflammatory cytokines and amyloid precursor protein within the brain among AD patients (Bondy, 2010).

Furthermore, AD is characterized by a gradual loss of cognitive functions and histopathologically by the presence of neurofibrillary tangles and senile, or neuric plaques (Haese and Broe, 2001). Other diseases that implicated from Al exposure are dialysis dementia and Parkinson (Nasir et al., 2010).

2.5.2 Dialysis Encephalopathy Syndrome

Dialysis encephalopathy is one of the main observations of the neurotoxicity of Al (Rondeau et al., 2000). Dialysis encephalopathy syndrome (also referred to as dialysis dementia) can result from accumulation of Al in the brain. Dialysis encephalopathy is a degenerative neurological syndrome, characterized by the gradual loss of motor, speech, and cognitive functions (Nasir et al., 2010).

Haese and Broe (2001) has stated the element's role in the development of the so-called Al-related dialysis dementia is now well recognized in dialysis patients. In addition, Krewski et al. (2009) indicated that Al exposure can developed such effect of dementia, facial seizures, encephalopathy and cognitive deficiencies. A total of 253 incident cases of dementia (17 exposed to high level of Al) were identified (Rondeau et al., 2000).

2.5.3 Parkinson's Disease

Al is a cellular toxin. An epidemiological study has found a correlation between this disorder and Al exposure. Studies have shown increased levels of Al in the Parkinson disease patients compared to controls (Altschuler, 1999).

2.5.4 Neurofibrillary Tangles

Some studies have reported that Al level in the bulk brain samples, neurofibrillary tangles (NFT) and plaques was higher in AD subjects than controls (Kweski, 2006). Perl and Brody (1980) found that Al is associated with NFT-bearing neurons, while normal neurons are free of Al. Thus, the association of Al with AD appears to be due to the association with NFTs. Krewski et al. (2009) found that Al can be used to characterise the AD disease as indicated by NFTs. Al also associated with disruption of neurotropic signalling in neurodevelopment processes (Howd and Fan, 2008).

2.5.5 Occupational Disease

Al in pot rooms of smelters is also associated to occupational asthma. Lungs and nervous system are the most sensitive targets of Al toxicity through inhalation exposure (Sorgdrager, 1997; Kongerud, 1994).The inhalation of dust heavily contaminated with Al, in an industrial environment, is recognized as a caused of pulmonary fibrosis, usually an interstitial fibrosis of the upper lobes of lung. Furthermore, Al exposure was also linked to pulmonary granulomatosis (Wills and Savory, 1985).

2.5.6 Skin Disease

Al is commonly found in deodorants due to the fact that it is easily absorbed through the skin and effectively blocks the sweat pores (Tharmakulanathan, 2004). There is limited information on dermal exposure of Al toxicity (ATSDR, 2008). Dermal irritation of compounds is evaluated by studies in animals and humans prior to testing of sensitization (Greim and Snyder, 2008). Application deodorants containing Al compounds to the skin, such as Al chloride in ethanol or Al sulphate, may cause rashes in some people.

2.5.7 Osteomalacia

Al appears to be major cause of osteomalacia and suppression of bone turnover in renal dialysis patients (Boyce et al., 1986). The osteomalacia was eventually attributed to Al toxicity following the detection of high levels of Al in serum and bone biopsy (Boyce et al., 1986). Bone pain, as a consequence of metabolic bone disease, is a common symptom in patients with chronic renal failure who are on a long-term intermittent haemodialysis treatment (Wills and Savory, 1985).

2.6 Exposure and Risk Assessment

2.6.1 Hazard Identification

Hazard Identification is the process of determining whether exposure to a stressor can cause an increase in the incidence of specific adverse health effects and whether the adverse health effect is likely to occur in humans. In the case of chemical stressors, the process examines the available scientific data for a given and develops a weight of evidence to characterize the link between the negative effects and the chemical agent (USEPA, 2010).

2.6.2 Dose-Response Assessment

A dose-response relationship describes how the likelihood and severity of adverse health effects (the responses) are related to the amount and condition of exposure to an agent (the dose provided) (USEPA, 2010). A dose-response relationship describes the increase in the probability of an adverse effect with corresponding increase in the exposure dose to the hazard. Therefore, some form of toxicological parameter must be used to describe the relationship in order to enable us to assess the health risk.

The first parameter is the Reference Dose (RfD) present in unit mg/kg/day is used to estimated daily oral exposure of a toxicant (Jamal and Zailina, 2010).

2.6.3 Exposure Assessment

Exposure assessment defined the amount of a chemical to which a population or individuals are exposed via inhalation, oral and dermal routes. Animal or human exposure is commonly defined by mg of the chemical per kg body weight per day (Greim and Snyder, 2008).

2.6.4 Risk Characterization

Risk characterization is the final step of baseline health risk assessment process (USEPA, 2010). It is the process of estimating the incidence of a health effect under the various conditions of human exposure describe in exposure assessment (Jamal and Zailina, 2010). Besides, the information from the hazard assessment, exposure assessment, and dose-response relationship helps scientists to estimate the extra risk to human health or the environment that is caused by toxic pollutants (CEPA, 2011)

CHAPTER 3

METHODOLOGY

3.1 Study Location

Study was conducted at Felda Palong, Negeri Sembilan (Figure 3.1). It is an area under the jurisdiction of Jempol District Council. Felda Palong was selected as study location because it provides a good context to assess the risk of Al levels since the quality treatment system is uncertain. In addition, there was no study done in Felda's settlers in previous study. The district water supply in Felda Palong is managed by Syarikat Air Negeri Sembilan (SAINS). The water treatment plant is located at Gemas, Negeri Sembilan.

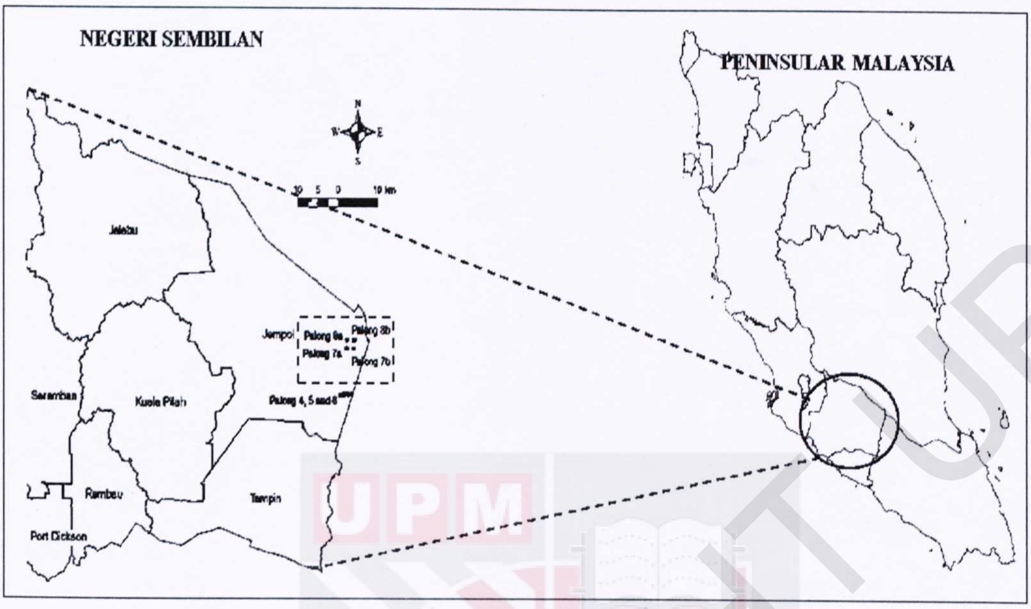


Figure 3.1: Study location (Felda Palong, Negeri Sembilan)

3.2 Study Design

This study was a cross-sectional study with the aim at determining health risk associated with the exposure of Al in drinking water especially in tap water among settlers of Felda Palong, Negeri Sembilan. These study designs are relatively easy and economical to be conducted and are useful for investigating exposures that are fixed characteristics such as use of tap water for drinking purposes

3.3 Study Population

The study population of this study was the settlers of Felda palong, Negeri Sembilan and who use tap water as the main source of drinking water.

3.4 Sampling

3.4.1 Sample Size

The sample size of the study was determined by calculation method by using the formula by Kirkwood and Sterne (2009). This calculation is for calculate single proportion only.

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

Where, N = Sample size

p = Prevalence

e = Probability error

According to Qaiyum et al. (2011), the prevalence of the Al violations at Mukim Parit Lubok (MPL) and Parit Raja (PR), Batu Pahat, is 70%. Standard error (e) = 0.05. Therefore, this prevalence is used in this study. So, the sample size was calculated:

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

$$N = \frac{0.7\,(1-0.7)}{(0.05)^2}$$

N = 84 respondents

To anticipate the non-response of respondents and missing data, size will be bringing to 100 respondents.

3.4.2 Sampling Method

The sampling method in this study is purposive sampling method. The respondents selected based on inclusive and exclusive criteria. Individual who exhibit the criteria that were selected from a study location until the required sample size is reached (100 respondents).

3.4.3 Sampling Unit

The sample unit for this study was the settlers that fulfil the inclusive and exclusive criteria. The inclusive criteria are adult Malaysians (≥ 18 years old) (Undang-undang Malaysia, 1971) who use the tap water for drinking and cooking. The exclusive criteria are tap water source was from other sources than district water supply and personal filtration systems are installed at the tap in the house.

3.5 Study Instrumentation and Data Collection

3.5.1 Questionnaire

Respondents who fulfilled the inclusive and exclusive criteria were asked to answer the administered questionnaire. Questionnaire contains three parts. First part was related to socio-demographic factors. Socio-demographic factors are requiring determine the status of the respondents including the age, races, monthly income and education background. The second part was related to housing area and tap water usage information. The third part was related Al level, pH level, water daily intake and body weight of respondents.

The questionnaire used was modified from the Baseline, Descriptive and Time-Activity Questionnaires used in NHEXAS-Arizona study (Dzulfakar et al., 2011; Kavcar et al, 2008). The questionnaire was translated into Malay version since it is the language that understood by most of the citizens. Data collection from the questionnaire such as body weight and daily water intake rate, the two most important parameters to be used in estimating chronic daily exposure also were recorded in questionnaire.

3.5.2 Water Sampling and Analysis

In this study, 250 ml high-density polyethylene (HDPE) bottles were used for tap water sampling and storage. The tap water was turned on and allowed to flow for 3 minutes in medium to high flow rate before samples were collected. The sample bottle was rinsed out at least three times with the tap water before it was filled to the top (WHO, 1971). Water samples (250 ml) were collected from each resident's tap water. Then, water samples were acidified to pH less than 2.0 with 0.5 mg/L of 69% acid nitric to preserve the sample (Kavcar et al., 2008). Preservation is important to prevent chemical reactions or both from occurring in the sample and could be stored up to 6 month before they were analysed in the laboratory (WHO, 1971). Two replicate of water samples from each house were collected for accuracy results and bottles were tightly cap and sealed in plastic bags. Items were kept in a clean place to avoid contamination (Lopez et al., 2001).

A LaMotte Orp TRACER PockeTester was used to measure pH. This instrument able to read the pH instantly by dipping the probe into the water and it can read from 0.00 to 14.00 with an accuracy of ± 0.01 (Figure 3.2).

Figure 3.2: LaMotte Orp TRACER Pocketester

Al level in water were analysed by using Pelkin Elmer Aanalyst 600 Graphite Furnace Atomic Absorption Spectrometer (Figure 3.3).

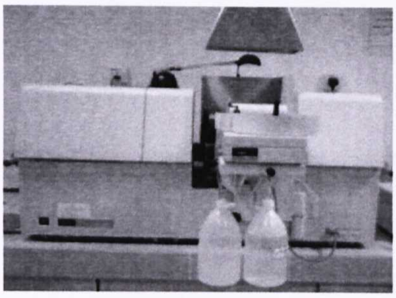


Figure 3.3: Pelkin Elmer Aanalyst 600 Graphite Furnace Atomic Absorption Spectrometer

3.5.3 Body Weight Measurement

Body weight of the respondents was measured with Seca Weight Scale. This is to determine the chronic daily intake. Body weight measurement has been taken three times and then averaged (Figure 3.4).

Figure 3.4: Seca Body Weight Scale

3.5.4 Geographical Information System (GIS)

A Geographical Information System interpolation technique was used to interpolate the distribution of Al level and the location. The locations of respondent's houses were obtained via Global Positioning System (GPS) tracker. The Al level was keyed in for each location and interpolate by ArcGIS 9.3 software to the distribution.

3.6 Quality Control

3.6.1 Standard Operating Procedure (SOP)

The analysis of water samples with Pelkin Elmer Graphite Furnace Atomic Absorption Spectrometer (GFAAS) was following the standard operating procedure (SOP) as given by the manufacturer. Other instruments pH meter which was operated as according with the SOP's given by the respective manufacturer. The reason to follow SOPs was to minimize analytical error.

3.6.2 Calibration

All instruments used were calibrated before used. This is to ensure the instruments are valid to be used.

3.6.3 Pre Test

Pre-test of questionnaire has been conducted on 10% of the sample size. This pre-test procedure was to ensure all questions were understood and could be answer by the respondents. Pre-test can avoid questionnaire bias and improve the result. Pre-test was performed at Felda Raja Alias, Negeri Sembilan on a voluntary basis.

3.7 Risk Assessment

Exposure of Al may occur via three main routes, which are ingestion, inhalation and dermal contact (Kavcar et al., 2008). In this study, only the ingestion route was taken into consideration in order to access exposure associated with Al in drinking water. Values all variables, specific to each participant, were used to estimate subject's individual chronic daily exposure level and calculated by using the equation below:

$$\text{CDI (Ingestion)} = \frac{(C_1) \text{ X } (R_1) \text{ X } (F_E) \text{ X } (Dt)}{(WB) \text{ X } (T_{AVG})}$$

Where, CDI (I) = Chronic daily intake (mg/kg/d),

C_1 = Level of Al level in drinking water (mg/L)

R_1 = Ingestion rate (L/day)

F_E = Exposure frequency (day/year)

Dt = Exposure duration (year),

WB = Body weight (kg)

T_{AVG} = Average of exposure duration (D × 365 days/year)

Values of input variables, specific to each participant were used to estimate subject's individual chronic daily intake. The hazard index (HI) was calculated to estimate non-carcinogenic risk:

$$HI = \frac{CDI}{RfD}$$

Where, HI = Hazard Index

CDI = Chronic daily intake (mg/kg/day)

RfD = reference dose (mg/kg/day)

A HI value of more than 1 implied a significant risk level. According to World Health Organisation, Reference dose for Al (RfD) is 7mg/kg/day (FAO and WHO, 1989).

3.8 Ethical Consideration

The permission to conduct this study was obtained from Committee of Ethical, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia. The purpose of study has been explained to respondents and a participant consent form was signed by the respondent before water sample were collected. The identity of the respondents including their personal information will remain confidential and individual data not going to be stated in any parts of the study or publication. After ethical considerations were approved by Ethic Community, Faculty of Medicine and Health Sciences the data collection were conducted.

3.9 Data Analysis

All data were analysed using Statistical Package for Social Science software (SPSS for windows version 20.0). Descriptive statistic was used to analyse descriptive data including socio-demographic data of respondents, information on water consumption and results of water analysis in frequency, percentage, means, standard deviation, ranges , maximum and minimum values.

The normality test in this study was performed using Shapiro-Wilk test where p value of Shapiro-Wilk test of greater than 0.05 would indicated a normal distribution data. Bivariate analysis (Pearson correlation test) was used for determination the relationship Al level in drinking water and pH level. One sample t-test was used to compare between Al levels at Felda Palong with National Standard for Drinking Water Quality.

3.10 Study Limitation

In this study, first limitation, this study only analysed the Al level from drinking water was sampled whereas there are other sources of Al into body such as food, medication, and occupational exposure. The second limitation, the water sample was taken once time only but water sample will be used to estimate the risk assessment for life of respondents and it may be not enough to support argument of risk for life of respondent and enough for basis study only.

CHAPTER 4

RESULTS

4.1 Socio-demographic data of respondent

The study was conducted in Felda Palong, Negeri Sembilan. A total of 60 adults were selected in this study based on the inclusion and exclusion criteria as been stated in Chapter 3. Table 4.1 show the socio-demographic data of respondents. The mean (standard deviation) (mean (SD)) for the age was 49 (14) years old and range between 18 to 66 years old. All respondents in this study were Malays, consist of 36 (60%) female respondents and 24 (40%) male respondents.

The highest education level of respondents was STPM with 1 (1.7%) respondent. There were 23.3% of the respondents have educational level until SPM, 11.7% of PMR, 50% of primary school and 13.3% have no formal education level.

The monthly incomes of respondents according to Malaysia Poverty Line (Economic Planning Unit, 2009) were ranged between RM750 to RM4000. Majority of respondents had monthly income in the range RM 750 until RM1999 (90%), followed by monthly income from RM 2000 to RM 3999 and more than 4000 which were 4 (6.7%) and 2 (3.3%) respectively.

Table 4.1: Socio-demographic data of respondent in Felda Palong

Variable	Mean (SD) (Years old)	Median (Years old)	Range (Years old)
Age	49 (14)	55	18-66

Variable	Category	Number of respondent (N)	Percentage (%)
Races	Malay	60	100
Gender	Male	24	40
	Female	36	60
Educational Level	No Formal Education	8	13.3
	Primary School	30	50.0
	PMR	7	11.7
	SPM	14	23.3
	STPM / Diploma	1	1.7
Monthly Income*	<RM750	0	0
	RM750-RM1999	54	90
	RM2000-RM3999	4	6.7
	>RM4000	2	3.3

N=60, * Malaysia Poverty Line (Economic Planning Unit, 2009)

The residence duration of respondents was range from 4 years to 38 years with mean (SD) was 29 (5) years. The duration of tap water uses was range from 1 to 38 years with mean (SD) was 25 (9) years (Table 4.2).

Table 4.2: Respondent's residence duration and duration of tap water uses

Variable	Mean (SD) (Years)	Range (Years)
Duration of residence (years)	29.38 (5.714)	4-38
Duration of tap water uses (years)	25.75 (9.538)	1-38

N=60

4.2 Aluminium level (mg/L) and pH level of water sample

Table 4.3 showed the result for Al level and pH of water sample. The Al level was range between 0.053 mg/L to 1.03 mg/L with mean (SD) was 0.292 (0.217) mg/L. The pH levels of water samples was range between 6.27 to 8.03 with mean (SD) was 6.865 (0.429).

Table 4.3: Aluminium level (mg/L) and pH Level of water sample

Variable	Mean (SD)	Range
Al Level (mg/L)*	0.292 (0.217)	0.053 – 1.030
pH Level*	6.865 (0.429)	6.27 – 8.03

N=60, * National Drinking Water Quality Standard (MOH, 2004)

The highest Al level was in Felda Palong 8 with mean (SD) of 0.347 (0.233) mg/L, followed by Felda Palong 6 (0.327 (0.205) mg/L), Felda Palong 7 (0.325 (0.147) mg/L), Felda Palong 5 (0.261 (0.21) mg/L) and Felda Palong 4 (0.323 (0.272) mg/L) (Table 4.4). Figure 4.1 indicate mean for Al level and the standard error in water sample by housing area.

Table 4.4: Description of aluminium level (mg/L) in Felda Palong

Variable	Number of respondent (N)	Mean (SD) (mg/L)	Range (mg/L)
Palong 4	10	0.223 (0.272)	0.053 – 0.986
Palong 5	20	0.261 (0.210)	0.056-0.759
Palong 6	9	0.327 (0.205)	0.143-0.731
Palong 7	8	0.325 (0.147)	0.138-0.598
Palong 8	13	0.347 (0.233)	0.150-1.030

Figure 4.1: Mean for aluminium level and the standard error in Water Sample by Housing Area

Distribution of Al level based on location has been interpolated by using Inverse Distance Weight (IDW) technique, the Geographical Information System (GIS) software. Figure 4.2 to Figure 4.4 shows distribution of Al level in Felda Palong 4,5,6,7 and 8. Al levels were interpolated from high levels (represented red) to low levels (represented green). Al was interpolated as high value in some area of Felda Palong 4 to 6, and on the East of Felda Palong 8.

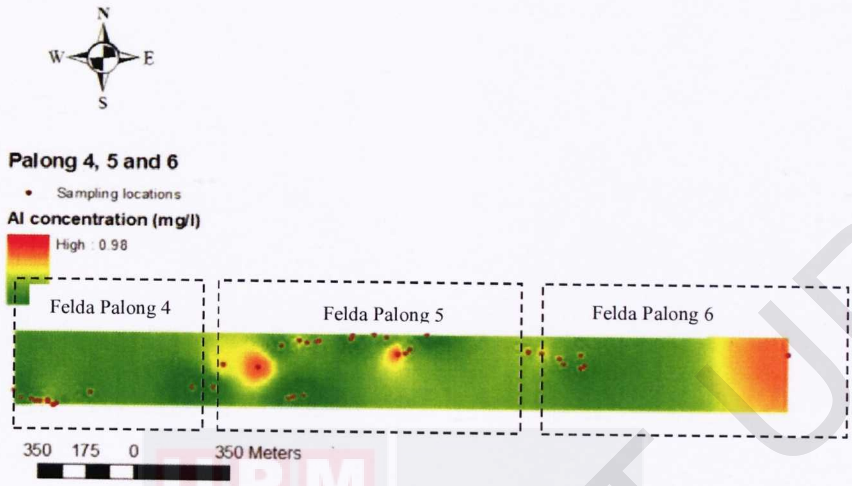


Figure 4.2: Aluminium level at Felda Palong 4, 5 and 6

Figure 4.3: Aluminium level at Felda Palong 7

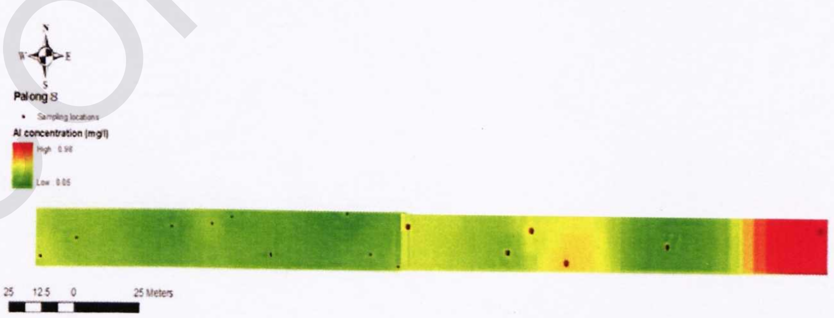


Figure 4.4: Aluminium level at Felda Palong 8

4.3 Comparison aluminium level (mg/L) of water sample with available standard

According to the National Standard for Drinking Water Quality (NSDWQ) by Ministry of Health, the acceptable value for Al in drinking water is 0.2 mg/L. Figure 4.5 shows 32 (53%) violations of Al level in this study to the NSDWQ value.

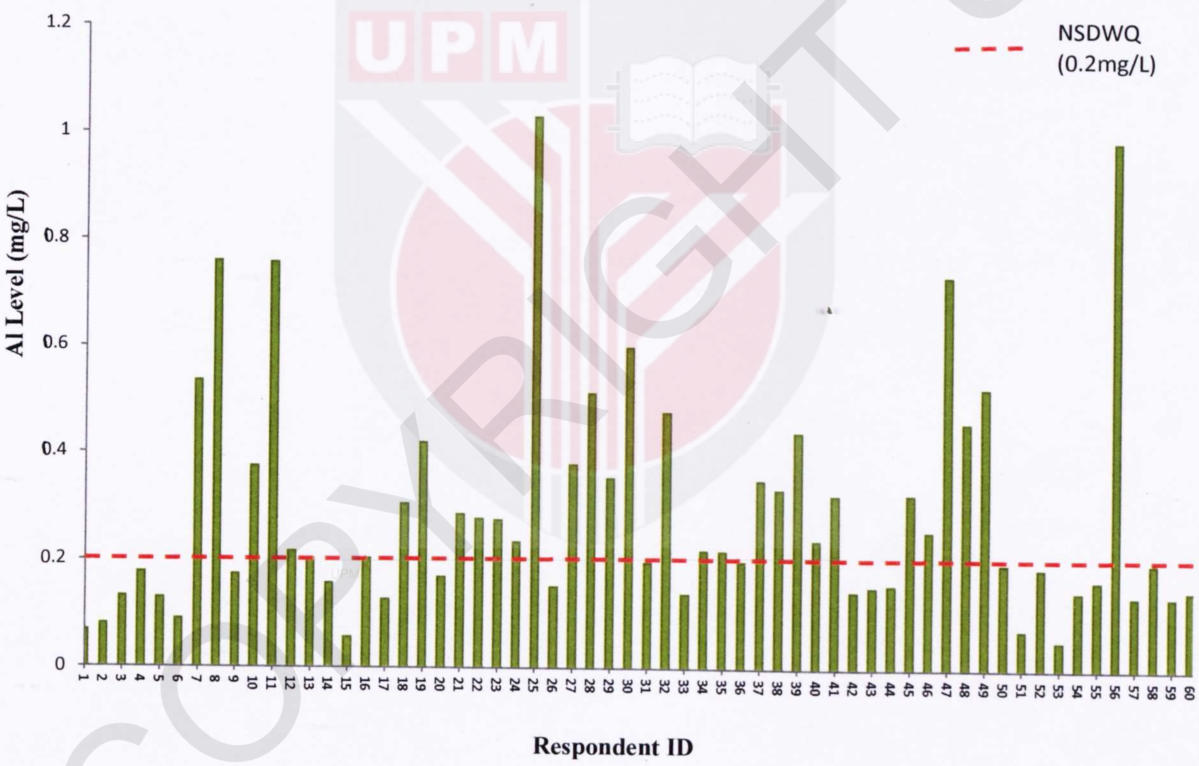


Figure 4.5: Comparison of aluminium level with NSDWQ Malaysia

Table 4.5 showed the description of Al level violation at Felda Palong. The highest violation was at Felda Palong 5 and Felda Palong 8 (10 violations), followed by Felda Palong 7 (6 violations) and Felda Palong 6 (5 violations) and Felda Palong 4 (1 violation).

Table 4.5: Description of aluminium level violation at Felda Palong

Places	Number of violation (N)
Palong 4	1
Palong 5	10
Palong 6	5
Palong 7	6
Palong 8	10

N = 60

According to NSDWQ, the acceptable value for water pH level is range between 6.5 to 9.0. There were 8 violations of pH levels at Felda Palong with value 6.305 to 6.475.

Table 4.5 showed the description of Al level violation at Felda Palong. The highest violation was at Felda Palong 5 and Felda Palong 8 (10 violations), followed by Felda Palong 7 (6 violations) and Felda Palong 6 (5 violations) and Felda Palong 4 (1 violation).

Table 4.5: Description of aluminium level violation at Felda Palong

Places	Number of violation (N)
Palong 4	1
Palong 5	10
Palong 6	5
Palong 7	6
Palong 8	10

N = 60

According to NSDWQ, the acceptable value for water pH level is range between 6.5 to 9.0. There were 8 violations of pH levels at Felda Palong with value 6.305 to 6.475.

4.4 Comparison of aluminium level between Felda Palong and NSDWQ Malaysia

Table 4.6 showed the comparison of Al level between Felda Palong and NSDWQ Malaysia. There were significant difference between Al level and NSDWQ Malaysia at z value of 0.02 ($p < 0.001$).

Table 4.6: Comparison of aluminium level between Felda Palong and NSDWQ

Variable	z	p
Comparison of Al level and NSDWQ	0.02	0.00

N = 60

4.5 Exposure Assessment

Respondents' chronic daily intake (CDI) was calculated using the CDI equation, including the parameter of Al levels in water, daily intake of water, duration of residence and body weight. Daily intakes of drinking water were range between 0.4 L/day to 7 L/day. The mean (SD) for drinking water was 1.613 (1.091) L/day. The body weights of respondents range between 34 kg to 100 kg with mean (SD) of 63.85 (14.349) kg. The CDI were range from 0.001 to 0.487 mg/kg/day. The mean (SD) for CDI was 0.008 (0.009) mg/kg/day (Table 4.7).

Table 4.7: Daily Intake (DI), Body Weight (BW) and Chronic Daily Intake (CDI) of respondents

Variable	Mean (SD)	Range
Daily Intake (L/day)	1.613 (1.091)	0.4-7.0
Body Weight (Kg)	63.85 (14.349)	34-100
Chronic Daily Intake (mg/kg/day)	0.008 (0.009)	0.001- 0.487

N=60

4.6 Hazard Index (HI) of Respondents

Hazard index (HI) is a summation of the CDI for chemicals to Reference Dose (RfD). A HI value of 1 or less than 1 indicates that no adverse human health effects (no cancer) are expected to occur. All the 60 respondents (100%) have HI less than 1. The mean (SD) of HI was 0.0011 (0.0012) (Table 4.8).

Table 4.8: Hazard Index of respondents

Hazard Index (HI)	Frequency (N)	Percentage (%)	Mean (SD)
HI < 1	60	100	0.0011 (0.0012)
HI > 1	0	0	0

N= 60

4.7 Relationship of aluminium level (mg/L) and pH level

Table 4.9 shows the relationship of Al level and pH level. There were significant relationship between Al level and pH level ($r = 0.29$, $p<0.05$). According to Guilford rule of thumb (Qaiyum et al., 2011), there were weak relationship between Al level and pH level. Figure 4.6 indicate the relationship of Al level and pH level.

Table 4.9: Relationship of aluminium level and pH level

Variables	p	r
Relationship of Al level (mg/L) and pH level	0.02	0.29

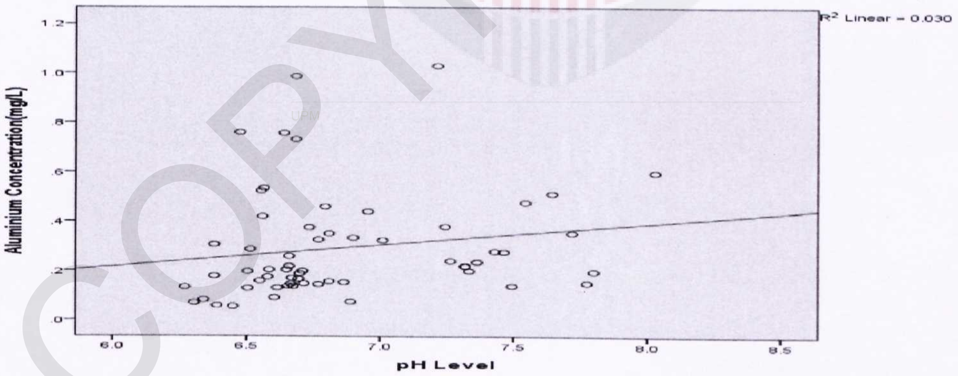


Figure 4.6: Relationship of aluminium level and pH level

CHAPTER 5

DISSCUSSION, CONCLUSION AND RECOMMENDATION

5.1 DISCUSSION

5.1.1 Socio-demographic data of respondents

A total of 60 respondents from Felda Palong 4,5,6,7 and 8 were involved in this study. Even though the sample size requires 100 respondents but after take consideration for inclusive and exclusive criteria and the respondents are decline to involved in this study, the total number was decrease to 60 respondents. The age of respondents range from 18 years old to 66 years old with mean (SD) was 49 (14) years old. Majority of respondents are in old generation because the young generation are move into city to further study or find job. All the respondents were Malays. This was in line with previous study that found that majority of the settlers in Felda were Malays (Hisham et al., 2010; Zulkifli et al., 2010).The number of female respondents higher compare to males, which were 36 (60%) respondents and 24 (40%) respondents, respectively. According to Felda's settlers basic information in Negeri Sembilan, the distribution of males is higher than females (Federal Land Development Authority, 2012) but many of male settlers refuse to be a respondents in this study. In addition, when we are conducting the survey, many of the respondents were housewives.

Majority of respondents have educational level up to primary school which was 30 (50%). Then, follow by SPM level, no formal education, PMR level and STPM or Diploma level which were 14(23.3%), 8(13.3%), 7(11.7%) and 1(1.7%) respectively. The educational data was similar with a previous study done in Felda Lurah Bilut. Out of the 273 respondents, it was found out that the highest level of education attained was SPM/MCE (6%), followed by SRP/LCE (6%). The majority of the first generation settlers (88%) only attained primary school education (Zulkifli et al., 2010). As all of them came from poor families, they did not have the chance to further their studies

Majority of respondents which was 54 (90%) had a monthly income in the range of RM 750 until RM1999. It is because the majority of Felda settlers have received the allowance for replanting palm oil or rubber. The replanting allowance was RM 1300 for settlers Felda Palong 7 and 8 while RM 1500 for settlers at Felda Palong 4, 5 and 6. There are settlers who received monthly income of RM 2000 and above. It is because they have side incomes from other jobs such as grocery shop and food stall.

5.1.2 Aluminium level (mg/L) and pH level of samples

5.1.2.1 Aluminium level (mg/L)

Al level in tap water at Felda Palong ranged between 0.053 mg/L to 1.03 mg/L with a mean (SD) of 0.292 (0.217) mg/L. According to a previous study by Qaiyum et al. (2011) the range of Al level from 2 different locations in Batu Pahat were 0.13mg/L to 0.23 mg/L (Mukim Parit Lubok) and 0.14 mg/L to 0.36 mg/L (Parit Raja), respectively. In addition, a study by Dzulfakar et al. (2011) have indicated the range of Al level in two areas in Pahang to be from 0.02 mg/L to 0.28 mg/L in Sungai Lembing and 0.05 mg/L to 0.26 mg/L in Bukit Ubi, respectively.

The mean (SD) of Al level in Felda Palong was 0.292 (0.217) mg/L. Mean of Al level from Felda Palong tap water showed higher than upper safe limit (0.2 mg/L) of NSDWQ Malaysia by Ministry of Health.

The mean of Al level at Felda Palong was higher than 2 previous studies in Malaysia. Study done by Qaiyum et al. (2011) at two villages in Johor resulted mean of Al level were 0.13 mg/L and 0.14 mg/L at Mukim Parit Lubok and Parit Raja, respectively. In addition, the other study in Pahang show mean of Al levels in drinking water were 0.11 mg/L and 0.12 mg/L (Dzulfakar et al., 2011). Mean of Al level from 2 previous studies were in line with upper safe limit (0.2 mg/L) of NSDWQ. Other than that, study by Farizwana et al. (2010) in Kota Tinggi indicated mean of Al level at public water supply level was 0.41 mg/L. The mean Al level was higher than Felda Palong and had violated the upper safe limit of standard.

The other study by Rubinos (2005) at Galicia (Northwest Spain) resulted mean of Al level at Coast-Galicia was 0.15 mg/L while inner-Galicia was 0.08 mg/L. According to Krewski et al. (2009), relevant exposure levels of concern for the general population identified as part of dose response assessment included neurological effects due to drinking water exposure (0.1 mg/L water). Animal models were supported biological plausibility of an association between Al exposure and the development of AD (Krewski et al., 2009). This supported by Gauthier et al. (2000) stated Al has been the most intensively studied neurotoxic substance among potential environmental risk factors for AD.

Rubinos (2005) also stated Al in drinking water will possibly produce effect on human because suspected connection of higher Al level with AD and other neurological disorders. In addition, experiment by Rondeau et al. (2000) derived the conclusion high Al levels in drinking water ($\geq$ 0.1 mg/L) were associated with an elevated risk of dementia and AD. The result is highly significant despite the small number of subjects exposed to such levels.

The mean of Al level from water samples from Felda Palong was higher than NSDWQ because a portion of the alum added to the high turbidity raw water is excessive to clean raw water and it lead to Al in that not fully removed during treatment. The extra Al levels will remains as residual Al in the treated water. There is considerable concern throughout the world over the levels of Al in drinking water sources (raw water) and treated drinking water (Singh et al., 2005).In addition, the conventional water treatment system used are not effeicient in controlling the release of residual of Al and not regularly maintained will lead to high Al levels in drinking water.

5.1.2.2 pH level

The pH level of water samples was range from 6.27 to 8.03 with mean (SD) was 6.865 (0.429). The result was different with previous study at 4 locations in Kota Tinggi which were 8.29 (0.34) (Tai Tak Estate), 8.65 (0.42) (Nam Heng Estate), 7.84 (0.45) (REM Eatate) and 7.06 (0.1) (SP Estate) (Farizwana et al., 2010).

High level of residual Al can be minimized by effective removal of particulate matter, particularly when raw water contains high level of total Al. The best way to control Al is optimization of the coagulation and filtration processes. To achieve optimal coagulation, the coagulant dosage and coagulation pH should be control. Optimizing coagulant dosage may entail increasing or decreasing the amount of alum added, depending on the specific conditions of the water treatment process. Adjustment of the coagulation pH to 6.0-7.0 provides the best results, as this is the range of minimum solubility of Al hydroxide (Health Canada, 2008).

The control of Al residuals can normally achieved within the pH range of 6.0 to 7.5. The minimum solubility of Al usually lies within this range (pH 6.0 to 7.0) (Dorea, 2008). Al being an amphoteric element, is soluble at extremely acidic (pH < 6) and alkaline (pH > 8.5) conditions, but is insoluble at near neutral pH values (7.0 to 7.5) (Srinivasan et al., 1999). Al solubility will consequently remain as residue in drinking water.

In conclusion the pH level in Felda Palong can affect the solubility of Al in water and can cause high Al level in drinking water. It is because the insoluble Al can be removed after coagulation and flocculation compare to the soluble Al that remain in treated water.

5.1.3 Comparison aluminium level (mg/L) and pH level of water samples with available standard

According to NSDWQ, the upper safe limit for Al in drinking water is 0.2 mg/L. There were 32 (53%) violations of Al level at Felda Palong, Negeri Sembilan. A previous study in the Palm oil estate water supply at Johor by Farizwana et al. (2010) showed the public water supply violated the Al standard with noncompliance percentages of 21.7%.

Another study by Qaiyum et al. (2011) at Parit Raja, Batu Pahat showed (70%) samples exceeded the upper safe limit (0.2 mg/L) of 50 samples collected, with the highest value attaining 0.36 mg/L. In addition, the number of Al violation in drinking water from Felda Palong is higher than a previous study by Rubinos (2005) in Galicia (Northwest Spain) (19% violations). Al levels in treated water above 0.3 mg/L in Felda Palong were caused by lack of optimization in the coagulation, sedimentation and filtration stages of the conventional method. This is due to the excessive amount of alum added during the water treatment process. The addition of alum was done only by observing the water turbidity, not according to the correct calculated required amount of alum (Farizwana et al., 2010).

According to NSDWQ by Ministry of Health, the acceptable value for water pH level is range from 6.5 to 9.0. There were 8 (13.3%) violations of pH levels at Felda Palong with value 6.305 to 6.475. The non-compliance of pH level in this study most probably due to irregular monitoring of pH levels before treated waters is released to the settlers. The noncompliance of pH level is similar with previous study at Australia. A previous study in New South Wales, Australia also indicated 46 (14.3%) non-compliance of pH levels due to non-compliance supply system have led to inefficient system in controlling pH levels (Li et al., 2009).

5.1.4 Comparison of aluminium level (mg/L) of water samples with NSDWQ

One sample t-test was used to analyze the difference in Al levels in drinking water from Felda Palong with NSDWQ (upper safe limit of 0.2 mg/L). There are significant difference between Al level and NSDWQ ($z = 0.02$, $p < 0.001$).

The result in Felda Palong was similar with previous study done by Qaiyum et al. (2011). From the binomial test, there was significant difference ($z = 0.50$, $p < 0.05$) between Al levels in drinking water at Parit Raja with the NSDWQ (Qaiyum et al., 2011).

This significance differences results indicate there are differences in Al levels in drinking water from Felda Palong with value recommended by NSDWQ. This value indicated the water treatmen system that not maintained and management of water treatment system was not efficient in controlling the residual of Al in treated water.

5.1.5 Exposure Assessment

The daily intakes of drinking water ranged between 0.4 L/day to 7 L/day. The mean (SD) for drinking water were 1.613 (1.091) L. The body weights of respondents range between 34 kg to 100 kg with mean (SD) of 63.85 (14.349) kg. The CDI were range from 0.001 mg/kg/day to 0.487 mg/kg/day.

The mean (SD) for CDI was 0.008 (0.009) mg/kg/day. When comparing mean CDI of Al intake between study location with Reference Dose (RfD) which is 7 mg/kg/day (FAO and WHO, 1989), CDI of Al intake for study location was lower than RfD. So, the Al intake was considered in acceptable level.

CDI of Al intake for Mukim Parit Lubok was in ranged of 0.00303 mg/kg/day to 0.01158 mg/kg/day, whereas for Parit Raja, CDI ranged from 0.0027 mg/kg/day to 0.01274 mg/kg/day (Qaiyum et al., 2011). CDI of Al intake in Felda Palong was higher than CDI in Johor. This is mostly due to high Al levels measured in drinking water in Felda Palong compared to study at Johor since the most contributable factor in CDI equation is Al levels rather than other factors such as respondents' body weight, daily water intake and exposure duration to Al in drinking water. The CDI was considered in acceptable level (reference dose) even though the Al levels were higher because the CDI equation develops internationally and there are differences value variables such as daily water intake (L/day) and body weight (kg) between international people and Malaysian.

5.1.6 Health risk assessment

Human health is closely related with the quality of drinking water. Various chemical pollutants in the drinking water can cause great risk to human health. In order to protect the safety of human consume drinking water, health risk assessment has been assessed (Li and Qian, 2011).

Hazard index is a summation of the RfD for all chemicals to which an individual is exposed. A hazard index value of 1 or less than 1 indicates that no adverse human health effects (no cancer) are expected to occur. All 60 respondents (100%) have hazard index less than 1. The mean of hazard index (SD) was 0.0011 (0.0012). This result was similar to a previous study by Qaiyum et al. (2011) at two residential areas in Batu Pahat. The result from this study was 100% for both locations showing HI lower than 1, which means that the risk was considered in acceptable level.

With the exception of a few key chemicals (such as arsenic, lead and fluoride) the risks of illness and death from chemicals are low, mostly speculative and unproven. There is little epidemiological data to support significant health risks from chemicals (Sobsey, 2006). In addition, studies have proven that human health risk caused by non-carcinogenic pollutants is acceptable and even can be ignored, and the human health risk is mainly caused by chemical carcinogenic pollutants (Li and Qian, 2011).

5.1.7 Relationship of aluminium level and pH level

There are significant relationship between Al level and pH level at ($p < 0.05$) and $r = 0.29$. According to Guilford rule of thumb, there were weak relationship between Al level and pH level.

The result is different by previous study done by Rondeau et al. (2000) and Farizwana et al. (2010). The previous studies showed indirectly proportional of Al level and pH level. It is plausible that the biological availability of Al is higher for low pH than for high pH, which would lead to an interaction between pH and Al. According to Farizwana et al. (2010), significant weak negative correlation was found between Al and pH levels ($r = -0.3$, $P < 0.05$).

This result indicates that the Al levels are also can be affected by changes in pH level. These because the Al levels change when there are changes on pH level of water samples.

5.2 CONCLUSION

In conclusion, this study showed that mean of Al levels in Felda Palong had exceeded the NSDWQ upper safe limit which is 0.2 mg/L. This study found that mean of Al levels in Felda Palong was higher than the NSDWQ.

There were week relationship between Al level and pH level. Health risk assessment prediction by calculating CDI and HI of respondents in this study, found that the CDI of water sample was lower than the Al Reference Dose (RfD) of 7 mg/kg/day (FAO and WHO, 1989). In addition, the hazard index value showed results of less than 1 which indicates risk exposure to Al in drinking water was below acceptable level. Respondents in Felda Palong were considered in acceptable level of non-carcinogenic risk of Al in drinking water which is related to diseases including AD.

5.3 RECOMMENDATION

Since there are 32 (53%) violations for Felda Palong, more action to reduce the Al level in drinking water must be taken into consideration by water treatment company in Malaysia to ensure safer treated water for the population. Water treatment plant which used Al sulphate (alum) as coagulant should be regular maintained and properly managed. The regularly maintenance and properly managed water treatment system can control the Al levels in treated water.

The authority such as Ministry of Health must regularly survey the Al level in drinking water and take action whether immediately or as soon as possible to overcome this problem because the accumulation of Al level will lead to health affect such as AD, dementia and Parkinson disease. Other than that, more risk assessment studies concerning the Malaysian particularly in rural population such as Felda population are necessary in order to improve the drinking water quality since results of this study showed that majority 32 (53%) settlers expose to Al in drinking water that above upper safe limit of Al standard by NSDWQ.

In addition, the residual Al can be eliminated by using several methods such as cation exchange resin, reverse osmosis and electrodialysis (Nasir et al., 2010). Although the methods are expensive but it wills efficient control the Al levels in drinking water.

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APPENDICES

FAKULTI PERUBATAN DAN SAINS KESIHATAN

FACULTY OF MEDICINE AND HEALTH SCIENCES
UNIVERSITI PUTRA MALAYSIA, 43400 UPM SERDANG, SELANGOR, MALAYSIA

PENERANGAN KEPADA PESERTA

TAJUK KAJIAN:

Kajian Risiko Kesihatan terhadap Pendedahan Baki Aluminium di dalam Air Minum di Kawasan Felda Palong, Negeri Sembilan

Terima kasih kerana membantu kami di dalam kajian ini.

1. Apakah kajian ini?

   Kajian ini adalah berkaitan dengan risiko kesihatan terhadap air minum di kalangan responden. Kandungan aluminium yang tinggi dalam air minum boleh menyebabkan kesan kesihatan seperti penyakit Alzaimer atau dikenali sebagai nyanyuk.

2. Apakah tujuan kajian ini?

   Kajian ini dijalankan bertujuan untuk mengkaji risiko kesihatan terhadap pendedahan aluminium di dalam air minum di kalangan penduduk Felda. Kajian ini menentukan sama ada penduduk terdedah atau tidak kepada risiko kesihatan yang disebabkan pendedahan aluminium dalam air minum.

3. Berapa ramai responden yang terpilih?

   Responden akan dipilih dari kalangan penduduk Felda Palong, Negeri Sembilan. Seramai 100 orang responden akan dipilih untuk kajian ini.

4. Apakah jenis ujian yang akan dijalankan?

   Semua responden akan diminta menjawab soalan yang dikemukakan oleh penyelidik berdasarkan borang soal selidik. Selain daripada itu, sampel air minum dari paip air di bahagian dapur akan diambil bagi proses analisis sampel air. Berat badan serta jumlah pengambilan air minum sehari untuk setiap respondent akan diambil dan dicatat oleh pengkaji.

5. Adakah bayaran dikenakan?

   Pengkaji akan menanggung segala pembiayaan ujian yang akan dijalankan dan tiada sebarang bayaran dikenakan terhadap setiap responden

6. Adakah maklumat dijamin sulit?

Semua maklumat yang diberikan oleh responden di dalam borang kaji selidik adalah dijamin sulit. Tiada huraian individu akan dibuat pada mana-mana bahagian di dalam kajian atau penerbitan.

7. Adakah hak anda?

Kajian ini melibatkan anda sebagai perserta secara sukarela. Oleh itu, peserta mempunyai hak untuk menarik diri dari penyertaan dalam kajian ini pada bila-bila masa sekiranya peserta merasa tidak selesa untuk memberikan maklumat kepada pengkaji.

8. Apakah yang harus anda lakukan?

Anda dikehendaki menandatangani borang penyertaan responden yang menyatakan minat anda untuk menyertai kajian ini. Ianya boleh dilakukan setelah anda membaca dan memahami isi kandungan penerangan ini. Borang penyertaan responden haruslah dikembalikan kepada penyelidik sebelum ujian dijalankan. Sekiranya anda mempunyai sebarang kemusykilan, penyelidik akan membantu untuk memberi maklumat yang selanjutnya.

Terima kasih atas kerjasama dan bantuan anda.

RAHIMAH SAPAI

Penyelidik

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FAKULTI PERUBATAN DAN SAINS KESIHATAN

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BORANG PERSETUJUAN RESPONDEN

TAJUK KAJIAN : Kajian Risiko Kesihatan Terhadap Pendedahan Baki Aluminium di dalam Air Minum di Kawasan Felda Palong, Negeri Sembilan

PENYELIDIK : Rahimah Bt Sapai

Saya...No.K/P...
alamat.............................. bersetuju untuk menyertai kajian bertajuk seperti di atas.

Saya telah membaca dan memahami isi kandungan kajian berdasarkan apa yang telah dinyatakan di dalam 'PENERANGAN KEPADA PESERTA' yang telah dilampirkan dan penerangan tambahan daripada penyelidik. Saya faham bahawa kajian ini dijalankan untuk mengenalpasti risiko kesihatan terhadap pendedahan baki Al di dalam air minum di kawasan Felda palong , Negeri Sembilan.

Saya juga faham bahawa segala maklumat yang diberikan dan segala keputusan yang saya perolehi adalah sulit dan hanya akan digunakan untuk tujuan penyelidikan dan rujukan penyelidik. Saya faham bahawa saya mempunyai hak untuk menarik diri pada bila-bila masa dan tiada sebarang tindakan boleh dikenakan ke atas saya atas tindakan tersebut.

Tandatangan: .... Tarikh :....................................

(*Responden*)

Saya mengesahkan bahawa saya telah menjelaskan kepada responden sifat dan tujuan penyelidikan seperti yang disebut di atas.

Tandatangan : .... Tarikh: ....

(*Penyelidik*)

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SELANGOR, MALAYSIA

BORANG PERSETUJUAN RESPONDEN

TAJUK KAJIAN : **Kajian Risiko Kesihatan Terhadap Pendedahan Baki Aluminium di dalam Air Minum di Kawasan Felda Palong, Negeri Sembilan**

PENYELIDIK : **Rahimah Bt Sapai**

Saya...No.K/P..
alamat............................. bersetuju untuk menyertai kajian bertajuk seperti di atas.

Saya telah membaca dan memahami isi kandungan kajian berdasarkan apa yang telah dinyatakan di dalam 'PENERANGAN KEPADA PESERTA' yang telah dilampirkan dan penerangan tambahan daripada penyelidik. Saya faham bahawa kajian ini dijalankan untuk mengenalpasti risiko kesihatan terhadap pendedahan baki Al di dalam air minum di kawasan Felda palong , Negeri Sembilan.

Saya juga faham bahawa segala maklumat yang diberikan dan segala keputusan yang saya perolehi adalah sulit dan hanya akan digunakan untuk tujuan penyelidikan dan rujukan penyelidik. Saya faham bahawa saya mempunyai hak untuk menarik diri pada bila-bila masa dan tiada sebarang tindakan boleh dikenakan ke atas saya atas tindakan tersebut.

Tandatangan: .... Tarikh :...................................

(*Responden*)

Saya mengesahkan bahawa saya telah menjelaskan kepada responden sifat dan tujuan penyelidikan seperti yang disebut di atas.

Tandatangan : .... Tarikh: ....

(*Penyelidik*)

BORANG SOAL SELIDIK

BAHAGIAN A

No Kad Pengenalan :

Nama:

Alamat:

No Tel. Rumah:

Bimbit:

1. Jantina
   Lelaki ☐ Perempuan ☐

2. Bangsa
   Melayu ☐ Cina ☐
   India ☐ Lain-lain ☐
   ....(Nyatakan)

3. Tahap pendidikan
   Sekolah Rendah ☐ PMR ☐
   Tidak belajar ☐ SPM ☐
   Pengajian Tinggi ☐ Lain-lain ☐
   ....(nyatakan)

4. Jumlah pendapatan isi rumah
   .... (Nyatakan)

BAHAGIAN B

5. Berapa lama tinggal di kawasan ini?
   ....(Tahun).........(bulan)

6. Apakah bekalan air yang digunakan
   Paip air JBA ☐
   Telaga ☐
   Gabungan diatas ☐
   Lain-lain ☐
   ....(Nyatakan)

7. Berapa lama anda menerima bekalan air paip
   ....(Tahun).........(bulan)

8. Berapa gelas air yang anda minum sehari
   ....Gelas sehari

9. Pernahkah air paip berbau?
   Ya ☐
   Tidak ☐

10. Pernahkah air paip mengalami kekeruhan

☐ Ya ☐ Tidak

11. Apakah sumber air yang anda kerap gunakan?

Air paip ☐
Air botol ☐

BAHAGIAN C: Kegunaan penyelidikkan

12. Berat badan responden

…………..KG

13. Kepekatan Al dalam air

…………..Mg/L

14. Adakah seringkali anda bersifat pelupa?

☐ Ya ☐ Tidak

15. Adakah ahli keluarga anda mempunyai sejarah penyakit Alzheimer (penyakit nyanyuk)?

☐ Ya ☐ Tidak

*Baseline, descriptive and time, National Human Exposure Assessment Survey (NHEXAS)-Arizona study (Kavcar et al., 2008)