UNIVERSITI PUTRA MALAYSIA

HEALTH RISK ASSESSMENT OF EXPOSURE TO IRON IN GRAVITY FEED SYSTEM WATER AMONG INDIGENOUS PEOPLE IN SUNGAI MAS VILLAGE, SUNGAI LEMBING, KUANTAN

NURUL ASHIKIN BT MOHD HANAFI

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BY:

NURUL ASHIKIN BT MOHD HANAFI

Thesis submitted in fulfilment of the requirement for the degree of Bachelor of Science in Environmental and Occupational Health with Honours from the Faculty of Medicine and Health Sciences, Universiti Putra Malaysia

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ABSTRACT

EXPOSURE TO IRON IN GRAVITY FEED SYSTEM WATER AMONG INDIGENOUS PEOPLE IN SUNGAI MAS VILLAGE, SUNGAI LEMBING, KUANTAN.

NURUL ASHIKIN BT MOHD HANAFI

Introduction: In Sungai Mas Village, Sungai Lembing, the gravity feed system is the principal source of drinking water. This study looked into the level of heavy metals such as iron in the water system to learn about and minimise any potential harmful health impacts on indigenous peoples who rely on piped-gravity water for their daily consumption. The water sources may be contaminated due to human activity. Furthermore, these gravity-feed system water catchments are an essential supply of fresh drinking water for rural areas. In Sungai Mas Village, the community comprises indigenous people who are a vulnerable group. Much research mentions the health effects of consuming too high a concentration of iron in drinking water can result in health problems such as hemochromatosis, Parkinson's disease, Huntington's disease, diabetes mellitus and neurological issues. **Objectives:** To determine the health risk exposure of iron level in drinking water from gravity feed system among residents at Sungai Mas Village, Sungai Lembing, Kuantan Pahang. **Methodology:** A cross-sectional research was carried out based on inclusion and exclusion criteria. The purposive sampling method was used to select respondents of jakun and semaq beri tribe. A total of 104 respondents were selected from the study area. This research had two parts; questionnaire, as well as water sample collection and analysis**.** Tap water was stored in 250 mL high-density polyethene (HDPE) bottles. Each house's tap water was collected straight from a pipe in the kitchen. The faucet was turned on, and the water was allowed to flow for 1-2 minutes before collecting the samples. pH and temperature were measured at the study location for all the water quality assessments, including iron levels. The iron level was determined using Hanna Instruments HI801-02 iris Visible Spectrophotometer, while the pH level was determined using EUTECH Cyberscan pH 310 Series Meter. **Results and Discussion:** Median and IQR of iron were 0.080 and 0.030 mg/L, respectively. There was no relationship between iron and pH levels of drinking water samples in the study area. There was no significant difference between iron levels in drinking water and the National Standard for Drinking Water Quality and the value ranged between 0.030 - 0.550 mg/L. There was no health risk of iron exposure among respondents. The HQ was <1. **Conclusion:** Generally, drinking water containing iron had no adverse health effects. The iron in drinking water in this study was not influenced. So there are no carcinogenic effects on the community in Sungai Mas Village, Sungai Lembing.

Keywords: ***Iron, Gravity Feed System Water, Health Risk Assessment, Chronic Daily Intake (CDI) Hazard Quotient (HQ)***

ABSTRAK

PENDEDAHAN KEPADA AIR SISTEM SUAPAN GRAVITI TERHADAP BESI DALAM KALANGAN ORANG ASLI DI KAMPUNG SUNGAI MAS, SUNGAI LEMBING, KUANTAN.

NURUL ASHIKIN BT MOHD HANAFI

Pengenalan: Di Kampung Sungai Mas, Sungai Lembing, sistem suapan graviti merupakan sumber utama air minuman. Kajian ini melihat tahap logam berat seperti besi dalam sistem air untuk mengetahui dan meminimumkan sebarang potensi kesan kesihatan yang memudaratkan ke atas orang asli yang bergantung kepada air graviti paip untuk kegunaan harian mereka. Sumber air mungkin tercemar akibat aktiviti manusia. Tambahan pula, tadahan air sistem suapan graviti ini merupakan bekalan penting air minuman segar untuk kawasan luar bandar. Di Kampung Sungai Mas, masyarakatnya terdiri daripada orang asli yang merupakan golongan yang terdedah. Banyak penyelidikan menyebut kesan kesihatan pengambilan terlalu tinggi kepekatan zat besi dalam air minuman boleh mengakibatkan masalah kesihatan seperti hemochromatosis, penyakit Parkinson, penyakit Huntington, diabetes mellitus dan masalah saraf. **Objektif:** Untuk menentukan pendedahan risiko kesihatan tahap zat besi dalam air minuman daripada sistem suapan graviti dalam kalangan penduduk di Kampung Sungai Mas, Sungai Lembing, Kuantan Pahang. **Metodologi:** Kajian keratan rentas telah dijalankan berdasarkan kriteria kemasukan dan pengecualian. Kaedah persampelan bertujuan digunakan untuk memilih responden suku jakun dan semaq beri. Seramai 104 orang responden telah dipilih dari kawasan kajian. Penyelidikan ini mempunyai dua bahagian; soal selidik, serta pengumpulan dan analisis sampel air. Air paip disimpan dalam botol polietilena berketumpatan tinggi (HDPE) 250 mL. Air paip setiap rumah dikutip terus dari paip di dapur. Keran dihidupkan, dan air dibiarkan mengalir selama 1-2 minit sebelum mengumpul sampel. pH dan suhu diukur di lokasi kajian untuk semua penilaian kualiti air, termasuk paras besi. Paras besi ditentukan menggunakan Hanna Instruments HI801-02 iris Visible Spectrophotometer, manakala paras pH ditentukan menggunakan EUTECH Cyberscan pH 310 Series Meter. **Keputusan dan Perbincangan:** Median dan IQR besi masing-masing adalah 0.080 dan 0.030 mg/L. Tiada hubungan antara kadar besi dan pH sampel air minuman di kawasan kajian. Tidak terdapat perbezaan yang signifikan antara paras besi dalam air minuman dan Standard Kebangsaan bagi Kualiti Air Minuman dan nilainya berjulat antara 0.030 - 0.550 mg/L. Tiada risiko kesihatan pendedahan zat besi dalam kalangan responden. HQ ialah <1. **Kesimpulan:** Secara amnya, air minuman yang mengandungi zat besi tidak mempunyai kesan kesihatan yang buruk. Zat besi dalam air minuman dalam kajian ini tidak dipengaruhi. Jadi tiada kesan karsinogenik kepada masyarakat di Kampung Sungai Mas, Sungai Lembing.

Kata kunci: Besi, Air Sistem Suapan Graviti, Penilaian Risiko Kesihatan, Pengambilan Harian Kronik (CDI)

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LIST OF ABREVIATIONS

CDI	Chronic daily intake
DI	Ductile iron
DRIs	Dietary Reference Intakes
FDA	Food and Drug Administration
FNB	Food and Nutrition Board
HQ	Hazard Quotient
RDAs	Recommended Dietary Allowances
RfD	Reference Dose
GFS	Gravity Feed System
GI	Galvanised iron
HD	Huntington's disease
HDPE	High-density polyethylene
HPLC	High performance or pressure liquid chromatography
HQ	Hazard Quotient
IDPH	Illinios Department of Public Health
IOM	Institute of Medicine
IQR	Interquartile Range
JAKOA	Department of Orang Asli Development
MOH	Ministry of Health
NHEXAS	National Human Exposure Assessment Survey
NIH	National Institutes of Health
PD	Parkinson's disease
SD	Standard Deviation

CHAPTER 1

INTRODUCTION

1.1 Research background

Sungai Mas Village, Sungai Lembing, relies primarily on gravity feed for drinking water. This study aims to identify and mitigate the potential adverse health effects caused by heavy metals like iron in the water system on Sungai Mas indigenous people who depend on piped-gravity water for their daily needs. Human activity may contaminate water sources. Additionally, gravity-feed catchment systems provide refreshing drinking water for countryside communities with no access to clean piped water from any water authorities (Shakeran, 2004). Indigenous people are communities that have inherited links to the land or assets on which they live. A strong connection exists between their identities, customs, livelihoods, physical and spiritual well-being, and the land. They often look to traditional leaders and groups for representation different or unique from mainstream society or culture. The history of injustice and isolation that indigenous peoples have experienced has made them particularly vulnerable to climate change and natural disasters. Indigenous people are described as small, isolated, uneducated and homogeneous, with a strong feeling of community relations (The World Bank, 2022).

According to the Governor (2022), the earth's crust contains more than 5% iron, making it a plentiful resource. During rainfall, iron dissolves in the land and causes geological structures, allowing it to flow into aquifers, which supply healthy water. It is rare for iron levels in drinking water to exceed ten milligrams per litre (mg/L) or ten parts per million (ppm). Water can change to red-brown with as small as 0.3 mg/L of iron. Typically, iron appears in water in two forms: soluble ferrous iron, and insoluble ferric iron. Water can dissolve and transfer these minerals into groundwater when it percolates through soil and rock. Iron pipes can also corrode and leak iron into the water supply (McFarland & Dozier, 2019).

According to (Ab Razak et al., 2015), in North Malaysia and the East Coast Peninsular Malaysia, most galvanised iron (GI) pipes have been substituted with ductile iron (DI) and mild steel (MS). As a result, based on World Health Organization (WHO), internal pipeline corrosion can introduce heavy metals such as iron into drinking water. Furthermore, based on Kavcar et al. (2009), several factors contribute to high trace metal levels in Izmir's drinking water, including the extensive use of metal galvanized iron pipes in Turkey's water distribution systems.

Furthermore, iron will give drinking water an unpleasant flavour and colour. Deteriorated pipelines, the supply of potable water, and unsanitary drinking water practices cause heavy metal pollution in drinking water. Iron is found naturally in soils and will permeate into water catchments. Heavy metal pollution is caused by anthropogenic operations such as inadequate wastewater treatment and fertilizer runoff such as mining, industrial, and agricultural activities. On the other hand, iron is generally removed during the water treatment process, as the bulk of heavy metals is in the surface and groundwater. Moreover, the Ministry of Health Malaysia has incorporated heavy metal characteristics in the National Drinking Water Quality Standard (NDWQS), which water authorities must meet to guarantee that the drinking water they give consumers is safe.

Water appearance or taste can indicate the presence of iron. For example, reddish-brown (iron) particles may be observed when water is drawn from the faucet.

These iron particles could come from rusted pipes or even the water supply. Because oxygen in the plumbing system oxidizes and precipitates the iron, the particles develop.

When substances or other dangerous factors appear in the natural environment, and a person may be exposed, a health risk assessment is conducted to determine what that person may experience adversely (NSW Health,2022).

In order to support the study's recommendation, through the literature review, the research study will improve our understanding of how water quality impacts human health. It will also improve our understanding of handling raw water quality challenges in rural areas. Several specialists familiar with the water resources and catchment challenges of Sungai Lembing have also contributed to the literature analysis.

1.2 Problem Statement

Even though a gravity-feed system water is a safe and dependable drinking water supply, geogenic pollutants such as iron can pollute it. There has been an association between long-term iron exposure and detrimental health outcomes in some regions due to increased groundwater use (Ghosh et al., 2020).

According to McDowell et al. (2022), serum ferritin levels greater than 300 ng/ml in men and 150 to 200 ng/ml in women during menstruation may indicate an iron deficiency. In addition, the excess of iron in the body can lead to other health effects. Although some metals, such as iron (Fe), are required for living organisms at specific doses, hazardous effects occur as concentrations rise. Therefore, drinking water containing substantial metals can negatively affect health (Kavcar et al., 2009).

As a result, it is essential to analyse the health risks faced by indigenous people who have hemochromatosis due to iron contamination in their drinking water. Furthermore, the water supply system that uses the gravity feed system does not undergo any treatment before being delivered to the residence (Roslan & Fadhil, 2017). As a result, indigenous people who rely on gravity feed system water as their principal supply of water, which may have a presence of iron without their knowledge, have a high risk of being exposed. Therefore, this study aims to determine whether the public's well-being is in danger due to iron levels in drinking water from gravity feed systems in Sungai Mas Village, Sungai Lembing, Kuantan, Pahang, in order to decide whether gravity feed systems are safe to consume.

According to Kamble (2020), high concentration of iron consumption also can lead to hemochromatosis, which is characterised by chronic weariness, arthritis, heart disease, cirrhosis, diabetes, thyroid sickness, dysfunction, and sterility. In addition, it spreads hepatitis B and C, as well as malignant colon, liver, stomach, and kidney tumours. Not only that, as a result, high iron levels can cause amenorrhea, cancer, constipation, diabetes, dizziness, emotional problems, fatigue, headache, heart damage, heart failure, hepatitis, high blood pressure, hostility, hyperactivity, infections, insomnia, irritability, joint pain, liver disease, weight loss, mental problems, metallic taste in the mouth, myasthenia gravis, and nausea (Afolabi, 2011).

1.3 Study Justification

By using the gravity feed system, this cross-sectional study aimed to calculate the possibility of iron contact for the village population of Sungai Mas Village. It has been chosen as the research location because its population is indigenous people, also known as a vulnerable group. Based on Ahmad et al. (2014), state that the abandoned mine influences heavy metal concentrations and distribution in surface water catchments near Sungai Lembing. However, no comparative research has yet been carried out in Sungai Mas Village, especially on iron through a gravity feed system. There is just no research relating to iron in gravity feed systems; however, other heavy metal in drinking water has already been done in the abandoned mine Sungai Lembing. The most recent research related to contaminated heavy metal in drinking water Sungai Lembing is in 2014 (Ahmad et al., 2014).

Moreover, the previous research on gravity feed system water in Malaysia was in 2017, including eight Peninsular Malaysia villages that do not include Sungai Mas Village. The research focuses on heavy metals such as, Ammonia (NH_3), Nitrate (NO_3), Ferum (Fe), Aluminum (Al), Manganese (Mn), Zink (Zn), and Cooper (Cu) (Roslan & Fadhil, 2017). As a result, I am willing to investigate iron in gravity feed system water in Sungai Mas Village.

The purpose of this study is to determine whether iron is still protected for direct consumption by rural residents who are dependent on gravity-feed water catchments for their livelihood in Sungai Mas Village. If raw water quality data from these gravity-feed catchments revealed poor water quality standards that posed significant threats to water users, we would investigate alternatives in the form of the best available water treatment practices acceptable to rural conditions that are costeffective to implement. Moreover, the study can raise knowledge and awareness about the health effects of heavy metals in drinking water. The results may be valuable in generating benchmark data for future research.

1.4 Research Question

There are many concerns in this research study. Therefore, the questions were formulated solely depending on the study's factors. The central questions that were addressed in these studies are as follows:

i. What is the level of iron and pH level of drinking water from gravity feed system water samples?
ii. Is there any relationship between iron levels and pH levels of gravity feed system water samples?
iii. Are there any differences between the Iron level of gravity feed system water samples in Sungai Mas Village, with acceptable Malaysian standards of iron in drinking water?
iv. What is the health risk among the study population of indigenous people in Sungai Lembing Village from ingesting exposure to iron in drinking water from a gravity feed system?

1.5 Research Objective

1.5.1 General Objective

To determine the health risk exposure of the iron level in drinking water from gravity feed system among residents at Sungai Mas Village, Sungai Lembing, Kuantan Pahang.

1.5.2 Specific objective

i. To determine the iron and pH levels of drinking water from gravity feed system water samples.
ii. To determine the relationship between iron levels and the pH level of gravity feed system water samples.
iii. To determine whether there is a difference between the iron level of gravity feed system water samples in Sungai Mas Village, with acceptable Malaysian standards of iron in drinking water.
iv. To determine the health risk among the study population of indigenous people in Sungai Mas Village, from ingesting iron in drinking water from a gravity feed system by calculating Hazard Quotient (HQ).

* Hazard Quotient (HQ) is the ratio between projected iron exposure and the threshold beyond which no harmful consequences are anticipated. The United States uses it primarily by the EPA to assess hazardous materials.

1.6 Research Hypothesis

i. There is a significant relationship between iron levels and the pH level of gravity feed system water samples.

ii. There is a significant difference between the iron level of gravity feed system water samples in Sungai Mas Village, with acceptable Malaysian standards of iron in drinking water.

iii. There is a significant major health risk of carcinogenic impacts among the study population of indigenous people in Sungai Mas Village from ingesting iron in drinking water from a gravity feed system if the Hazard Quotient score is more than one (HQ >1).

1.7 Study Variables

Independent variable: Level of iron concentration in gravity feed system water Sungai Mas Village, Sungai Lembing Kuantan

Dependent variable: Health risk assessment exposure of iron among indigenous people in Sungai Mas Village, Sungai Lembing, Kuantan

1.8 Definition of Terms

Research title:

Health Risk Assessment of iron Exposure in a Gravity Feed System among Indigenous People in Sungai Mas Village, Sungai Lembing, Kuantan.

<u>Health risk assessment</u>

Conceptual:

According to the US Environmental Protection Agency (EPA) (2021), human health risk assessments estimate the type and probability of adverse health consequences for individuals exposed now or in the future to pollutants. Risk assessment consists of four steps: hazard identification, dose-response assessment, exposure assessment, and risk characterization.

Operational:

Health risk assessments collected among indigenous people living in Sungai Mas Village who consume water from a gravity feed system. Questionnaires was employed to assess the health risk assessment of indigenous people. There was information that collected through questionnaires such as demographic characteristics – age, gender and weight were all indicators of physical wellness and some disease symptoms (Wellness platform, 2015). Calculation of the Hazard Quotient (HQ) can be used to analyze the health risk assessment. HQ score is less than one, and no significant health risk from non-carcinogenic impacts was anticipated. This hazard quotient can be calculated using formula of hazard quotient for heavy metal.

<u>Exposure to Iron in Drinking Water</u>

Conceptual:

According to Governor (2022), in water supplies, iron is toxic. Iron dissolved in water as rainwater seeps into aquifers to the groundwater. The iron in drinking water is hardly exceed than ten mg/L or ten parts per million. With as little as 0.3 mg/l, water can turn reddish brown. Water has two forms of iron: soluble ferrous iron and insoluble ferric iron. Due to its total dissolution, ferrous iron is colourless and transparent. Water exposed to air or atmosphere becomes hazy and turns reddish brown. Water will not dissolve ferric or oxidized iron.

Operational:

Filled a transparent beaker halfway with water and set it aside. Iron concentrations as low as 0.3 milligrammes per litre (mg/l) may be enough to generate reddish-brown silt because iron is usually not toxic at this concentration (Robinson, 2017). There was two types of analysis involved which were physical and chemical characteristics. Physical water characteristics examine a water sample's temperature, colour, taste, and odour. Water's chemical qualities include factors like pH and dissolved oxygen. The unit involves mg/litres.

<u>Indigenous People</u>

Conceptual

According to United Nations (2022), indigenous peoples inherit and practice diverse cultures and ways of cooperating with the natural environment. Despite being dominant societies, they have kept rare community, social, financial, and diplomatic traits. Even though indigenous peoples from all over the world have different cultures, protecting their rights as separate peoples poses similar challenges. Indigenous people were among the most vulnerable and disadvantaged groups in the world.

Operational

Indigenous people aged 18 years old and above lived in Sungai Mas Village.

1.9 Conceptual framework

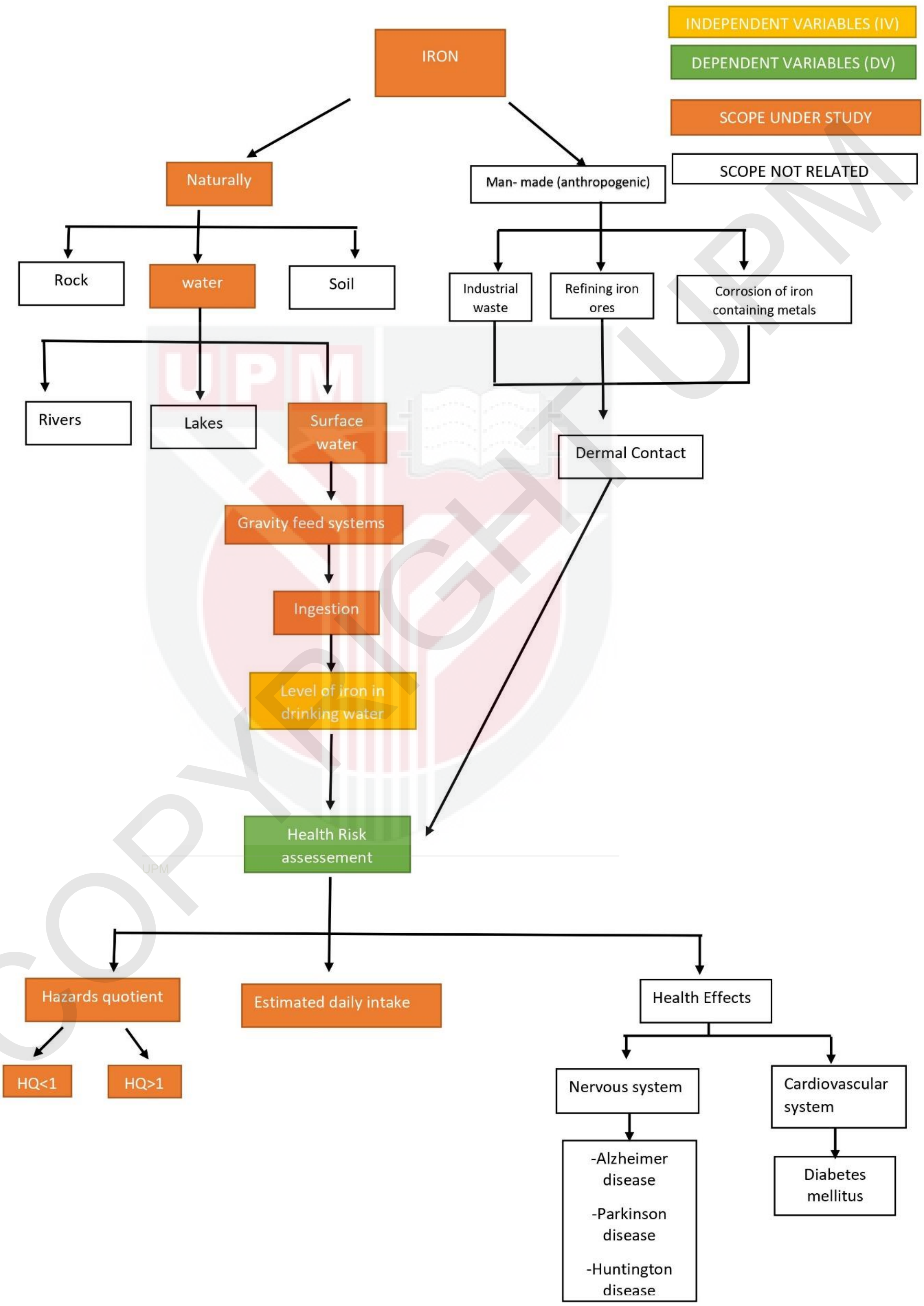

Figure 1.1: Conceptual Framework of the study

- Iron compounds in soils and rocks were dissolved in acid water; the higher the iron concentration, the lower the pH of the water (Clean Water Guys, 2018).
- Iron release occured naturally in rivers, lakes, and subterranean water due to manufacturing wastes, iron ore refinement, and rust of iron-containing metals.
- In Sungai Mas Village, the principal source of drinking water was the gravity feed system. Therefore, heavy metals such as iron, in the water system was investigated in this study to learn about and minimise any potentially harmful health impacts on indigenous peoples who rely on piped-gravity water for their daily requirements.
- The ingestion route was indirect exposure through food and water into the gastrointestinal systems. According to the authors, skin exposure was less influence than inhalation and ingestion (Ab Razak et al., 2015). They also indicated that heavy metal inhalation intake was often lower than ingestion. The three most common heavy metal exposure mechanisms were absorption, inhalation, and ingestion. Therefore, consuming water through ingestion was the primary source of heavy metal pollution in drinking water.
- According to the Ministry of Health Malaysia's National Standard Drinking Water Quality, the maximum allowable concentration is 0.3mg/litre.
- In Ghosh et al. (2020), a health risk assessment approach developed by the United States Environmental Protection Agency was employed to assess exposure to iron-contaminated groundwater through drinking gravity feed system water.
- No significant non-carcinogenic effects were expected to pose a health risk if the HQ score was less than one (HQ <1) (Ghosh et al., 2020).

CHAPTER 2

LITERATURE REVIEW

According to Ford et al. (2017), in the year 2000, the United Nations authorized the Millennium Declaration. As a result, the Millennium Development Goal (MDG) was created to reduce the number of people without access to clean drinking water. However, water accessibility does not imply that water sources were safe to drink. Rural communities were at greater health risk due to inadequate water testing and risk mitigation.

In nature, iron was typically found with Mn, whereas Cd, Pb, and Zn were frequently seen together. Galvanized steel was commonly used because it was made from Zn-Pb ores and contained Cd as an auxiliary metal. According to this study, the iron contents grow with the age of the taps and pipes (Wątor et al., 2021).

A human health risk assessment has been used to approximate individual risk exposure since the late 1940s (Ford et al., 2017). However, the term "health risk assessment" (HRA) first appeared in the 1980s. This was a quantifiable approach to determining the relationship between environmental contaminants and human health. The health risk assessment procedure was approved by the United States Environmental Protection Agency (USEPA) and was widely used in countries all over the world. This research employed the HRA technique to evaluate the health hazards of groundwater consumers by computing the HI (Hazard Index) to provide suggestions, zone, check, and manage water resources (Li et al., 2021).

Heavy metals in groundwater were derived from ecological ores, industrial or craft waste. Because iron-containing minerals such as pyroxene, ambifon, magnetite, pyrite, biotite, and others dissolved into weak and stable dissolved iron oxides (Fe^{2+} and Fe^{3+}). Groundwater generally includes iron. When iron protooxide molecules were shown to be oxygen or oxidizing agents, they break down into iron hydroxides, which occur as colloids in water. The water smells strange and rises to the top when the iron level in groundwater surpasses 0.05 mg/l. Therefore, iron-containing water will harm our goods and clothing (Li et al., 2021).

2.1 Definition of iron

Earth's surface was rich in iron. On the periodic table, iron is the 26th. Iron was required for practically all living organisms to thrive and survive. Mining operations were the primary source of iron in surface water (Jaishankar et al., 2014). According Gregersen (2022), the most common iron minerals in nature were magnetite, hematite, goethite, and siderite.

The iron component was released into the water due to weathering processes. Iron carbonate was found in both mineral and drinking water. Iron was used commercially worldwide and was produced in quantities of 500 million tonnes per year. Every year, 300 million tonnes of waste are recycled. The primary reason was that iron might be employed in more applications than any other metal. Alloys lessen the corrosiveness of the metal. Containers, automobiles, laundry machines, bridges, houses, and even little springs were made from iron alloys. Iron compounds were used as pigments in making glass as well as pharmaceutics, chemicals, iron fertilizers and insecticides. These were also employed in wood impregnation and photography (Lenntech,2022).

Iron was discovered in numerous foods and was accessible as a nutritive supplement. In addition, iron was vital for haemoglobin, an erythrocyte (red blood cell) protein that carries oxygen from the lungs to the tissues. Fe ionic radius, physiological valence charge, absorptive processes for humans, and enrichment in groundwater settings all have a significant relationship (Elsner & Spangler, 2005).

Ions type and concentration in water, redox state, microbial activity, and the dissolution of rock minerals were some of the environmental factors that influence the presence of Fe in groundwater under normal conditions. The groundwater-surface water interaction mechanism substantially impacts Fe dilutions in aquifers in sandy regions where groundwater is intensively applied for farming and drinking (Kim et al., 2008).

Data reveal that groundwater Fe concentrations are higher than those of the upper river. Under anoxic conditions, Fe discharge can occur quickly under the present laterites covering the neighbouring area, which may correlate with high-level total Fe concentrations in the groundwater (Kim et al., 2008).

According to the Illinois Department of Public Health (2010), iron is the majority of heavy metal in American tap water, accounting for 5% of daily requirements. In addition, iron was a vital element for almost all living things since it was interested in numerous metabolic methods, such as oxygen transport, DNA creation, and the movement of electrons. However, because iron may generate free radicals, the amount in body tissues must be carefully monitored because too much might injure tissues (Abbaspour N et al., 2014).

According to Ibrahim Mohammed Ibrahim, N. (2016), iron in groundwater is usually caused by dissolving iron-bearing minerals and rocks. Iron atoms can be soluble or insoluble when reduced from Fe^{3+} to Fe^{2+} (ferric hydroxide and ferrous bicarbonate). Soluble Fe^{2+} was the most common dissolved iron at pH levels ranging from 5 to 8. When groundwater is drained to the outside, oxygen (O_2) penetrates the solution and initiates the oxidation method, causing the groundwater to emit carbon dioxide (CO_2) into the atmosphere. As a result, the pH rises, changing the soluble Fe^{2+} mineral to the insoluble Fe^{3+} mineral.

The growth of iron bacteria depends heavily on the pH level and can occur in a range of 5.5 to 8.2, with 6.5 being the ideal level for iron.

2.2 Definition gravity geed system (GFS)

The gravity feed system was a system that used gravity to transport clean water from higher altitudes (waterfall, lake) to lower altitudes, the reservoir, and eventually to the people for daily consumption. The water, however, was untreated. This system had provided daily moisture to the locals for decades, continuing in service until the district got water pipe construction from the Jabatan Kerja Raya. A single dam may provide direct fresh water to roughly 70-80 households (Rambo,2011).

Research by Roslan and Fadhil (2017) supported that 4,878 Gravity Feed Systems in Malaysia were part of a Ministry of Health effort to supply safe water to rural residents, with most of GFS systems operating without treatment. In general, due to the quick expansion of the economy, the systems were vulnerable to contamination and deterioration of water quality. Malaysia's government prioritises safe water delivery in both urban and rural areas. Actions have been taken in association with the Ministries of Rural and Regional Development and Health to enhance the value of the life cycle in countryside regions and ensure safe water quality. The Ministry of Health (MOH) was participating in the BAKAS (Rural Water Supply and Sanitation) initiative, which includes gravity feed systems (GFS) programmes.

Furthermore, the water condition of eight Gravity Feed Systems in eight distinct communities was examined during the research. Microbiological, physical, and chemical contamination were evaluated utilising intake samples. The water condition tests were typically within the allowable range of the Drinking Water Quality Standard except for E. coli and turbidity (Roslan & Fadhil,2017).

2.3 Level of iron and pH value

According to the Ministry of Health Malaysia National Standard Drinking Water Quality, the maximum allowable concentration for iron is 0.3mg/litre. Based on Metzger (2005), asserts that the pH of the water was critical in affecting iron solubility and biological availability. The graph below depicts the relationship between pH and iron levels, demonstrating that iron concentration rises as pH increases. Lowering the pH below 6.5 promotes the structure of iron accumulations in solutions, which can lead to rust problems (Ibrahim Mohammed Ibrahim, 2016). Furthermore, because acid water dissolves iron compounds in soils and rocks, the lower the pH of the water, the greater the iron content (Clean Water Guys, 2018).

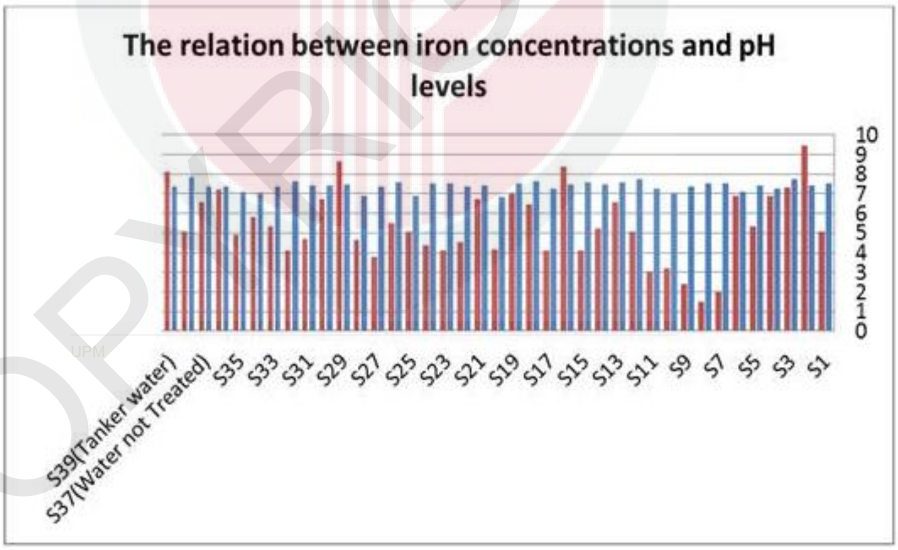

Figure 2.1: Graph relation between iron concentrations and pH levels

(Source: Ibrahim Mohammed Ibrahim,2016)

According to APEC Water Systems (2022), water with a pH of fewer than 6.5 was frequently acidic, soft, and corrosive. Metal ions such as iron, manganese, copper, lead, and zinc may be present in acidic water. To put it another way, acidic water was high in toxic metals. In addition, acidic water may corrode metal pipework prematurely.

According to Huang et al. (2015), the quantities of Fe were discovered to be adversely linked with pH level. The presence of Fe in groundwater varied significantly seasonally and may have been influenced by changes in the aquifer's environmental conditions.

The connection between pH and iron. To begin, classify pH as the number of hydrogen ions present. This intensity was determined using the negative logarithm of the hydrogen ion (H^+) intensity; hence, the greater the pH, the fewer free hydrogen ions were present. Furthermore, a difference in pH suggests a ten-fold change in hydrogen ion concentration. More specifically, a pH of 7 releases ten times more hydrogen ions than a pH of 8, while a pH of 6 releases 100 times more than hydrogen ions. The pH ranges from 0 to 14, with 7 signifying neutrality. Therefore, everything under seven is acidic, and everything above seven is alkaline or basic.

pH water was crucial as it can affect the solubility and physical accessibility of nutrients, particularly alloys like iron. The quantity of a chemical that can dissolve in water is referred to as its solubility, and the more soluble iron is, the lower the pH level. The quantity of substance consumed by aquatic life was known as its biological availability. Iron comes in various forms: microbial, organic, colloidal, soluble (ferric hydroxide), and soluble (ferrous bicarbonate). Insoluble iron, often known as red water iron, is instantly noticeable upon pouring a glass. The tint of the water might be rusty or yellowish. Rust, also known as ferric hydroxide, is created when the environment oxidises the iron.

According to the Minnesota Department of Health (2022), iron may occasionally be produced from water pipes or well casings made of steel or iron corroding.

Clear water iron was another name for soluble iron. The iron may initially look clear after pouring a glass, but over time it will oxidise into particles and sink to the bottom of the glass. Finally, an acid was combined with organic iron. The acid might be translucent but usually has a yellowish-to-red colour.

Acidic water often causes corrosion issues when levels are below 6.5 and tends to hold minerals in solutions. This described the formation of rust when insoluble iron is exposed to air, causing the pH of the water to drop and the iron to oxidise. In addition, insoluble iron compounds, such as ferric hydroxide or iron carbonate, were produced by bacteria.

2.4 Conjugation of iron

According to Hach (2022), iron in groundwater frequently appears in the ferrous (Fe^{2+}) or resolvable form, which quickly oxidises to ferric (Fe^{3+}) iron when exposed to the atmosphere. Discharge of organic sediments, iron-containing manufacturing wastes, pickling discharges, or acidic mine drainage can introduce iron into a water system. Illegal logging was also going on in the forest surrounding Sungai Mas Village. As a result, there were propose two ways to identifying Fe(II) and Fe(III):

(1) spectrophotometric approach for clear water solutions and

(2) EPR-spectrometric technique for cloudy liquids and tissue homogenates.

According to Jan AT et al. (2015), in a World Health Organization (WHO) research, 47.4% of children aged 1 to 5, 25.4% of group-aged children, 41.8% of prenatal and 30.2% of non-prenatal women, 12.7% of males, and 23.9% of the senior residents endure from iron deficiency anaemia. Fe^{2+} facilitated lipid peroxidation appears following the attachment of Fe^{2+} to negatively charged phospholipids, which leads to a variation of the physical properties of the phospholipid bilayer, followed by the beginning and propagation phases of lipid peroxidation.

$$Fe2+ + ROOH \rightarrow RO\bullet + OH\bullet + Fe3+$$

$$Fe3+ + ROOH \rightarrow RO2\bullet + H+ + Fe2+$$

It was valued stated that iron, as a component of haemoglobin, reduces the toxicity of Pb. Its weakness has occurred associated with increased Pb toxicity to the hemopoietic system. Compared to a regular iron load, iron insufficiency in anaemic patients has been demonstrated to have a considerable effect on Pb. It competes for absorption at the gut surface with hazardous metals, shielding the body from damaging repercussions. Its enhanced existence also prevents to overcome of heavy metal competitive binding to active regions of enzymes, which prevents them from functioning. -aminolevulinic acid dehydratase (-ALAD) and ferrochelatase was two outstanding examples of Pb-inhibitable enzymes (Jan AT et al.,2015).

According to the Cleveland Clinic medical professional (2022), most metals that cause poisoning enter the human body in a tiny molecular form. People will not be able to notice them since they are so tiny. Heavy metals can enter your body through food or water that contains the metal. Heavy metal poisoning can occur in anyone exposed to heavy metals.

2.5 Sources of iron

According to Health Canada (2009), when the pH exceeds 7, iron is detected in surface waters as salts, including Fe (III). The bulk of these salts was unsolvable or became adsorbed on surfaces. As a result, iron concentrations in well-aerated waters were rarely high. However, Fe (II) concentrations can remain high in some groundwaters, ponds, and lakes when conditions are reduced and without sulphide or carbonate. Weathering of rocks and minerals, acidic mine water drainage, landfill leachates, manure effluents, and iron-related companies were all sources of iron in natural rivers. In addition, using dirty water for irrigation, using fertilisers and metal-based pesticides, transportation, harvesting, and storing can cause heavy metal contamination (Maigari et al., 2016).

2.5.1 Daily intake

According to the National Institutes of Health (2021), heme and nonheme iron make up dietary iron. Plants and iron-fortified foods contain nonheme iron, while beef, fish, and poultry contain both heme and nonheme iron. In addition, 10% to 15% of Western cultures consume heme iron, formed when iron reacts with protoporphyrin IX in the air to give the complex FeCl (PPIX).

2.5.2 Food

Based on Health Canada (2009), meal iron content varies considerably. Breakfast cereal (mean: 0.0295 mg/g) and beef (mean: 0.0262 mg/g) were the principal nutritional resources of this component. The iron level of most other organic foods is less than 0.020 mg/g. Foods enriched with iron or made with iron may have higher amounts. Evidence suggests that when meals are cooked, the iron content decreases.

Lean beef and seafood were excellent sources of heme iron. Nonheme iron can be observed in nuts, legumes, vegetables, and fortified grain products. Breast milk has a high-level concentration of bioavailable iron, but not sufficient to satisfy the demands of babies above the age of 4 to 6 months. The bioavailability of heme iron was higher than nonheme iron (National Institutes of Health, 2021).

Dietary Reference Intakes (DRIs) for iron and other minerals were provided by the Food and Nutrition Board (FNB) of the Institute of Medicine (IOM) of the National Academies. "DRI" refers to source values used to plan and evaluate nutritional intakes. These were some of the ideals that fluctuate according to age and gender:

Table 2.1: Recommended Dietary Allowances (RDAs) for Iron

Age	Male	Female	Pregnancy	Lactation
Birth to 6 months	0.27 mg*	0.27 mg*		
7–12 months	11 mg	11 mg		
1–3 years	7 mg	7 mg		
4–8 years	10 mg	10 mg		
9–13 years	8 mg	8 mg		
14–18 years	11 mg	15 mg	27 mg	10 mg
19–50 years	8 mg	18 mg	27 mg	9 mg
51+ years	8 mg	8 mg		

* Adequate Intake (AI)

(Adapted from: National Institutes of Health, 2021)

2.5.3 Environments

According to statistics from a few Canadian drinking water locations, iron levels in drinking water were typically less than one mg/L and even less common than 0.3 mg/L. Insoluble iron was the most prevalent iron found in aqueous systems, and most water treatment processes removed it. For example, in 1985, the average iron level of raw water in Ontario was 0.339 mg/L, whereas preserved water had a value of 0.046 mg/L (Health Canada, 2009).

Suppose everyday water intake for an average Canadian adult was estimated to be 1.5 L, and the average iron content of Canadian drinking water was assumed to be 0.046 mg/L. In that case, the average daily adult consumption of iron from drinking water was roughly 0.07 mg/mL (1985 Ontario mean concentration). A daily intake of 0.9 mg/mL has been determined in Europe. As a result, iron consumption from food exceeds drinking water.

2.5.4 Pharmaceuticals

Several individuals might need an iron enhancement regularly to stabilise their iron concentrations. However, a daily multivitamin pill with iron should be enough for most individuals (News Medical Life Sciences, 2019).

Iron-fortified multivitamin/multimineral supplements, particularly those targeted towards women, often contain 18 mg of iron (100 per cent of the Daily Values (DV)). Men's and seniors' multivitamin/multimineral tablets sometimes contain little or no iron. Iron-only supplements were often higher in iron than DV, with various providing 65 mg (360 per cent of the DV).

Ferrous sulphate, ferrous gluconate, ferric citrate, and ferric sulphate were ferrous compounds used in supplements. Due to its excellent solubility, ferrous iron was more easily absorbed in dietary supplements. However, consuming too much iron (45 mg or more daily) may make people feel nauseated and constipated. Heme iron polypeptides were less likely to cause adverse gastrointestinal effects than iron amino-acid chelates.

Various iron supplements contain different amounts of essential iron. For example, there was 33% elemental iron in ferrous fumarate, 20% in ferrous sulphate, and 12% in ferrous gluconate. Customers do not have to figure out how much iron was in different types of iron supplements because essential iron was mentioned in the Supplement Facts panel. An estimated 14% to 18 % of Americans use iron supplements. In addition, iron supplementation was used at various rates based on age and gender, with 6% of children aged 12 to 19 years using it, 60% of nursing mothers using it, and 72% of pregnant women using it.

According to National Institutes of Health (NIH) (2021), calcium may interfere with iron absorption, although this impact has not been definitively demonstrated. As a result, some doctors advise people to take calcium and iron supplements at different times of the day.

2.5.5 Air

According to Health Canada (2009), the presence of iron in the atmosphere was influenced by releases from the blade industries, thermal power plants, and ignition.

2.6 Route of exposure

According to Health Canada (2009), every day, the skin, faeces and urine excrete less than 1 mg of endogenic iron. As a result, humans lose extremely little iron through the gastrointestinal tract, the skin and urine. Losses were more significant in menstruating women due to blood loss. Hepcidin, a blood-circulating peptide hormone, is an essential regulator of iron uptake and supply through the body, including in blood plasma (National Institutes of Health,2021).

Heavy metals enter the human body by ingesting, absorbing, and inhaling them. Inhalation routes involve direct contact with heavy metals via the skin and respirational system, in which the metal vaporizer or aerosol in the air is breathed into the lung. In contrast, ingestion routes involve indirect exposure via food and drinking water into the gastrointestinal tract. According to scientists, skin exposure was less critical than inhalation and ingestion (Ab Razak et al., 2015). They also indicated that heavy metal inhalation intake was often lower than ingestion. The three most prevalent heavy metal exposure methods were absorption, inhalation, and, eventually, ingestion. As a result, drinking water was the most common source of heavy metal exposure. Because of the low levels of heavy metals in Malaysian drinking water, health risk evaluations of heavy metal absorption routes through drinking water may go unreported. However, because intake rate was one of the factors in the HRA calculation, a high-level rate of drinking water by the residents may boost the risk of exposure.

According to Maigari et al. (2016), heavy metals enter the body via inhalation, ingestion, and skin absorption after being discharged into the natural environment via air, water, food, or various artificial items. The body's detoxification systems cannot quickly remove heavy metals from genetic tissues, causing a gradual toxic buildup. Therefore, exposing the body to high concentrations was unnecessary to produce poisonousness; heavy metal accumulation occurs gradually in body tissues and can reach unsafe levels above permissible limits.

2.7 Health effects

According to Olalekan et al. (2018), a shortage of iron in the blood can induce anaemia, while too much can cause the body to create free radicals, speeding the ageing process. Therefore, ingestion of drinking water containing substantial iron concentrations can have negative health consequences. High body iron storage was thought to be caused by high quantities of iron in the groundwater in rural Bangladesh. On the other hand, overexposure to iron can lead to health problems such as Parkinson’s disease, Huntington’s disease, cardiovascular disease, type 2 diabetes, pigmentation changes, Alzheimer’s disease, and renal, hepatic, respiratory, and neurological disorders are all possible (Ghosh et al., 2020).

2.7.1 Hemochromatosis

According to Peninsula Water (2022), even though iron is a necessary element, it must be eliminated from drinking water. This was due to its numerous adverse health effects. For example, the consumption of significant amounts of iron causes hemochromatosis, a disorder in which standard regulatory systems fail to function correctly, resulting in tissue damage due to iron buildup. However, dietary excess was rarely the cause of this disease.

Furthermore, too much iron in water generates an excess, resulting in diabetes, hemochromatosis, stomach problems, and nausea. It may also harm the liver, pancreas, and heart (Peninsula Water, 2022). According to a Cleveland Clinic medical professional (2021), hemochromatosis was more frequent in elderly adults since iron toxicity takes years to develop. So, if a person consumes iron in their drinking water for years, hemochromatosis will develop. Hemochromatosis was a hereditary medical disorder in which your intestines fail to absorb iron effectively. Hemochromatosis can cause tiredness, weight loss, disorientation, and liver cirrhosis. However, hemochromatosis is a genetic disease, and drinking well water with high-level iron concentration cannot cause it (Woodard, 2019). Hemochromatosis affects men more than women. This was because women lose iron when they get their periods or have children. In addition, their bodies store less iron. According to Bacon et al. (2022), ferritin concentrations of more than 300 ng/mL in men and 200 ng/mL in women indicate hemochromatosis. Ferritin is a protein that determines how much iron is in the body. Ferritin levels in the blood rise when the body's iron storage build; however, ferritin levels do not usually rise until iron stores are high. Long-term ingestion of acidic meals cooked in iron cookware has also caused tissue damage (Health Canada, 2009).

2.7.2 Diabetes Mellitus

According to The British Diabetic Association (2019), hemochromatosis is an extra iron that accumulates in organs such as the pancreas. It then affects the pancreas, causing it to produce insufficient insulin. For glucose (sugar) to enter our cells, insulin was necessary. People with untreated diabetes have too much glucose in their blood because they do not have enough insulin. As a result, a rise in iron levels in our blood may harm our pancreas. This shows that it was unable to produce insulin efficiently. Hemochromatosis causes secondary diabetes in this way.

2.7.3 Parkinson’s disease

Based on Wolozin and Golts (2002), several studies have connected iron to the pathophysiology of Parkinson's disease (PD). Iron levels were elevated, and iron-binding protein levels were abnormal in the brains of Parkinson's disease patients. Because Fe (II) was known to produce oxidative damage, iron has been linked to Parkinson's disease. According to Powers et al. (2003), researchers investigated the relationships between Parkinson's disease and dietary factors such as minerals, vitamins and lipids. Subjects in the highest iron intake quartile had a greater incidence of Parkinson's disease than those in the slightest.

According to Minn (2003), those with the highest iron intake — the top 25% — were 1.7 times more prone to acquire Parkinson's disease than those with the lowest iron intake. Oxidative stress may destroy dopamine-producing brain cells, also affected by Parkinson's disease. Parkinson's disease was almost twice as common in individuals who consumed the most significant iron (Boyles, 2003).

2.7.4 Huntington disease (HD)

Much research provided evidence that iron may play a substantial role in HD (Xiao et al., 2013). Furthermore, iron buildup in the central nervous system was connected to neurodegenerative illnesses such as Alzheimer's disease, Parkinson's disease, Huntington's disease (HD), amyotrophic lateral sclerosis, and neurodegeneration with brain iron buildup. As a result, the disruption of genes engaged in iron metabolism is necessary to cause neurodegeneration (Agrawal et al., 2018).

2.7.5 Neurodegeneration

Based on Farina et al. (2013), excessive exposure to heavy metals, such as iron, might result in pathological disorders such as neurodegeneration. Based on Rajendran et al. (2021), elevated metal levels in the body make it easier for them to go to numerous organs, including the brain, causing physiological problems. The neurotoxin causes of metals produce dementia and cognitive impairment, leading to neurodegenerative disorders. Although iron was necessary for cellular equilibrium, high levels were linked to several neurodegenerative disorders.

However, if iron is insufficient, it could have a few adverse health impacts. First, iron is a secondary or cosmetic contaminant, even if it posed no health risks. Iron was necessary for healthy health and aided blood oxygen transportation. However, a shortage of oxygen can cause anaemia in a person. Today, most anaemias in wealthy nations are caused by poor iron consumption or bioavailability, but only around half of the anaemia in developing nations. When you have anaemia, your body does not create adequate healthy red blood cells to provide enough oxygen to your tissues. Being anaemic, or having low haemoglobin levels, can cause fatigue and frailty. Anaemia is classified into several forms, each having its cause (Mayo clinic, 2022).

Drinking low iron levels is not harmful to your health. The Environmental Protection Agency (EPA) regulates iron as a secondary pollutant. Secondary pollutants were contaminants with visual and cosmetic implications, such as bad tastes and stains but are not deemed unsafe to ingest. Iron is essential for a healthy, balanced diet because it aids red blood cell formation and carries oxygen through the body (Woodard, 2019).

2.8 Types of iron

According to Woodard (2019), when iron comes into contact with oxygen and water, it begins to oxidise and fade. During prolonged exposure to the environment, iron degrades and becomes rusty. Tap water pipes may need to be replaced to fix this.

Three kinds of iron may be found in tap water. Removing iron from tap water requires a detailed and precise understanding of the kinds of iron present. Because of its shape, iron poses distinct issues and answers. In order to remove it, we must first determine what form the iron is in.

2.8.1 Iron ferric

Iron ferric is one of the simplest forms of iron to remove from tap water. It was insoluble iron, implying that iron minerals have not dissolved entirely in water. If tap water is vivid orange or red, it contains much ferric iron. Bacterial iron is the most straightforward type since it exists as a precipitate form (Woodard, 2019).

2.8.2 Ferrous iron

It has entirely dissolved in water since ferrous iron is soluble iron. Ferrous iron appears crystal clear in a field glass. Even though ferrous does not show immediately, exposure to air conditions and oxidized water will become ferric and precipitate. Reddish-brown particles would appear in clear water if left on a shelf overnight. The taste and odour of your water will be affected by ferrous iron, which has discolouration properties. A deep well usually has ferrous iron since it has been exposed to less daylight and has not oxidized (Woodard, 2019).

2.8.3 Bacterial iron

Bacterial iron was the most challenging and deadly kind of iron in tap water. Bacterial iron is formed when bacteria in tap water form connections with iron. Bacterial iron shows as a bright red sludge. Bacterial iron was frequently detected in wells due to inadequate good protection or poor tuning. For instance, if your good pump was repaired but not thoroughly sterilised before returning to the well, germs might enter and bond with the iron. Bacterial iron clogs well pumps clog plumbing fittings and leaves a muddy, slimy reddish residue in toilet bowls and tanks. Bacterial iron can also cause problems with water softeners, sediment prefilters, and booster pumps. Though bacterial iron is not inherently toxic, it can promote the growth of deadly pathogenic bacteria (Woodard, 2019).

2.9 Method to remove iron in drinking water

According to Kent Health Care Products (2022), there were few types of iron in the water. Ferric iron is an oxidised form of iron that precipitates as yellow, brown, or red and changes the colour of the water to yellow or brown.

On the other hand, ferrous iron does not affect water colour. It does, however, provide a metallic flavour to water. In a nutshell, if water appears brownish or yellowish and has an unpleasant flavour, it contains iron. One method was to oxidise the water to convert all ferrous iron to ferric iron and filter it. Oxidation can be accomplished by chemical injection, catalytic medium, or aeration. Once all of the iron has become ferric, it may be filtered.

2.9.1 Remove iron ferric

2.9.1.1Sediment filters

A sub-micron sediment filter may remove the iron precipitation accumulated in the water. Sediment filters provide a free water flow while keeping solid particles out of home plumbing. Water filtration systems remove debris, silt, and opacity from the water supply. Check that the sediment filter has a micron rating that is fine enough to collect iron. Many good owners select natural cotton string wound sediment filters to catch and eliminate the ferric iron in the tap water supply. This solution was appropriate for persons with low iron levels because it is entirely ferric. There is, however, no guarantee that a sediment filter will cure discoloured latrines or metallic-tasting water if your tap water contains ferrous and ferric iron.

Figure 2.2: Neo-Pure PH-27097-S35 9-3/4" High Efficiency Pleated Filter 0.35 micron

(Source: Kent Health Care Products, 2022)

2.9.2 Remove ferrous iron

2.9.2.1 Water softeners

Ion-exchange water softeners may remove trace amounts of ferrous iron from water. Water softeners generally employed ion exchange to eliminate water hardness minerals from water by replacing sodium ions with positively charged mineral ions. Because iron was a positively charged cation, it was attracted to the spherical anion resin beads and replaced with a sodium ion, just like calcium and magnesium ions. If ferric iron is in the water, a sediment pre-filter will be essential to inhibit iron slugs from clogging your water softener.

Water softeners were also the most effective at eliminating iron from hard water. A sufficient ratio of water hardness and iron must be present for the ion exchange to remove iron from water efficiently. An oxidising filter will be extra effective in lowering the iron content if it is soft water. Furthermore, water softeners were effective in removing ferrous iron from water. Water softeners cure hard water minerals but may also remove ferrous iron. However, you should use specialist iron filters if your water has a significant iron level.

Figure 2.3 :Neo-Pure® High Efficiency Up-Flow Series Water Softener

(Source: Kent Health Care Products, 2022)

2.9.3 Remove bacterial iron

2.9.3.1 Shock chlorination

Removing bacterial iron from tap water takes time, but getting rid of the slimy, intrusive infection is well worth the effort. Shock chlorination was putting a large amount of chlorine (approximately 200 ppm) into a well to sterilize the water and the physical well ultimately. Shock chlorination must be applied to the entire depth of a well in order to achieve effective results. The well's whole depth, walls, well pump, and pressure and distribution systems were all included. It is possible to recover residual iron by using a softener, oxidizer, or sediment filter to kill the bacteria causing the iron to bind in the well. If the well does not sufficiently remove the bacterially constrained iron, you may need to install a continuous chlorination system after your retention.

CHAPTER 3

METHODOLOGY

3.1 Study location

The research location was Sungai Mas Village, Sungai Lembing, Kuantan (Lat/Long 3.912753, 103.032744). Sungai Mas Village was located in the sub-district of Kuantan in the state of Pahang. Health Inspector Ministry of Health stated that the “Sungai Mas Village sources of drinking water are from gravity feed system water” (Fauzi, personal communication, March 16, 2022). The total population of Sungai Mas Village is 104 households.

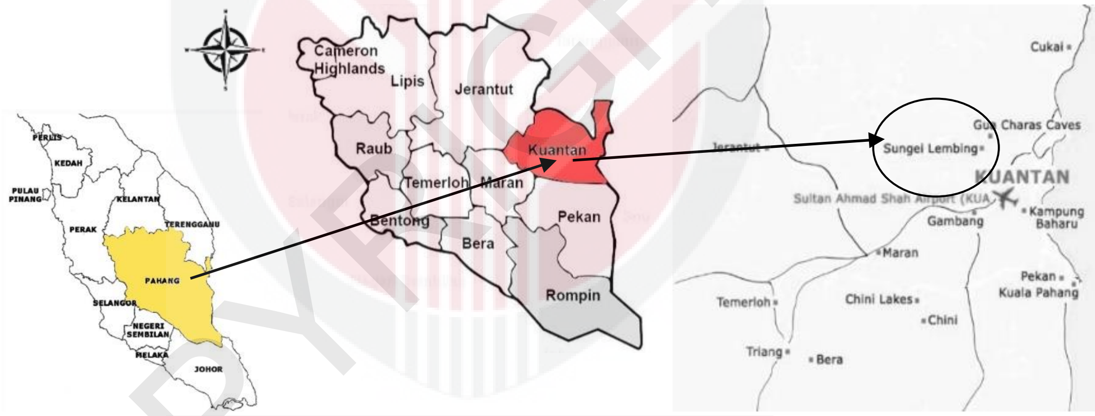

Figure 3.1: The location of sampling point

3.2 Study design

A cross-sectional study design was conducted in Sungai Mas Village, Sungai Lembing, Kuantan, for a health risk assessment exposure to iron in gravity feed system water among Sungai Mas Village population.

3.3 Study duration

The research starts from April to December 2022, a total of approximately eight months duration. Data collection was conducted from 18th August to 19th August 2022.

3.4 Study population

This research's study population consists of either male or female indigenous people which from jakun and semaq beri tribe who drank treated gravity feed system as their main source of drinking water.

3.5 Sampling

3.5.1 Sampling population

Inclusion criteria

i. The inclusion criteria were indigenous people of 18 years old and above who live in Sungai Mas Village, Sungai Lembing, Kuantan.

ii. The respondents must use gravity feed system as drinking water.

iii. Residents shall lived at least a year in Sungai Mas Village, Sungai Lembing. The reason for residents to live the least a year is that hemochromatosis is more frequent in elderly adults since iron toxicity takes years to develop (Cleveland Clinic medical professional, 2021)

Exclusion criteria

i. Respondents who were using a water filter system at home.

3.5.2 Sampling frame

It includes all the respondents who fulfilled the inclusion criteria.

3.5.3 Sampling unit

Residents of Sungai Mas Village must fulfil the inclusive requirement of being an adult Malaysian aged 18 and over who uses treated gravity feed systems as their primary source of daily drinking water. Residents who drink bottled water or use a water filter at home were excluded.

3.5.4 Sampling methods

The purposive sampling method was used to select respondents for this study. All respondents' names were obtained from the village head. Purposive sampling was used because the respondents were chosen based on inclusion criteria. Moreover, a limited number of primary data sources may contribute to the study, and it is the only relevant approach available. Also, purposive sampling was the most cost- and time-effective way. The water sample and questionnaire review for health risk assessment were taken at the respondent's house who fulfilled the inclusion criteria after receiving approval from JKEUPM and consent from the Department of Orang Asli Development (JAKOA) to conduct the study.

3.5.5 Sample size

Kirkwood and Sterne (2003) established the following formula for calculating sample size:

$N=p(1-p)/e^2$, where:

N= sample size

p= prevalence of high iron in drinking water

e= sampling error (0.05)

Prevalence= Which is total no of sample that exceed limit / total number of sample taken.

=42/85

=0.49

Sample size determination calculation:

$N=0.49\ (1-0.49)/(0.05^2)$

$=0.49\ (0.51)/\ (0.0025)$

$=99.96$

100 respondents.

The prevalence (p-value) was determined by a study by Muhammad et al. (2010). Therefore, the quantity of respondents in this study is 100 respondents. Besides, 10% of the non-response rate should be considered, where the minimum respondent should be at least 110.

3. 6 Instruments and data collection

3.6.1 Iron analysis

Hanna Instruments HI801-02 iris Visible Spectrophotometer, that can measure all visible light wavelengths, was used to analyse iron. Iron detection limits in this method ranged from 0.00 to 5.00 mg/L as Fe. The iron high-range reagent was also utilised, with a resolution of 0.01 mg/L. For natural and treated waters, the method adapts the EPA Phenanthroline method 315B (Hanna Instruments, 2022).

Figure 3.2: Hanna instrument HI801-02 iris Visible Spectrophotometer for iron analysis

(Source: Hanna Instruments,2022)

3.6.2 pH analysis

A pH meter, the EUTECH Cyberscan pH 310 Series, was used to determine the pH. By dipping the probe into the water and reading it fast, this apparatus could test the pH from -2.00 to 16.00 with an accuracy of 0.01 (Rshydro,2022). pH may be tested both outdoors and in the lab. However, the pH must be determined within 2 hours after the sample was collected, if it is examined in the lab. This is because carbon dioxide from the air dissolves in water, causing the pH to climb toward 7.

Figure 3.3: The EUTECH Cyberscan pH 310 Series for pH

(Source: Rshydro,2022)

3.6.3 Body Weight

A digital body weighing equipment of Omron Body Composition Monitor with Scale was used to determine each respondent's body weight.

Figure 3.4: The digital body weight for body weight

(Source: OMRON Healthcare, 2022)

3.6.4 Questionnaire

The questionnaire was adapted from the National Human Exposure Assessment Survey (NHEXAS) conducted in Arizona (Lebowitz et al., 1995). A questionnaire was administered among the indigenous people of Sungai Mas Village, Sungai Lembing, to analyse the respondents' health risk assessments. Representative respondents were chosen from 104 households. Male and female respondents with primary education were included in the research. The ages of the adults ranged from 18 to 60 years old. Age, body weight, occupational exposure, waterborne infections, daily water intake, and other health concerns were obtained throughout the questionnaire survey. Respondents from the study area carefully filled out the questionnaires. Survey team members also questioned residents personally, and the questions were worded carefully to minimise misinterpretation. In addition, the questions were occasionally explained in their native language by survey team members. The questionnaire also provided an area for comments to encourage respondents to answer freely and contribute their thoughts. This survey is done throughout the research region, with all questions coming from the users of each water source. The questionnaire was based on a study by Singh and Sharma (2019), and divided into three sections:

Section A: Socio-demographic factor and information on family background.

Section B: Health status

Section C: Information on drinking water at home

3.6.5 Water sampling in drinking water process

The main objective of water sampling is to track and quantify how water quality varies over time. Therefore, both the sampling techniques and the analysis were crucial. During selection and transportation, care must be taken to prevent unintentional sample contamination.

Sampling and pH should all be checked because they will alter during storage and transportation. Furthermore, there should be a delay between the sample and analysis. It is advised to store liquids in glass or plastic bottles at a low temperature (for example, four °C, 39 °F) and the dark (Niederbacher & Nahold, 2005).

In this study, tap water was stored in 250 mL high-density polyethene (HDPE) bottles. Many research employed HDPE bottles to collect water samples for heavy metals analysis (Ghosh et al., 2020). Each house's tap water was collected straight from a pipe in the kitchen. The faucet was turned on, and the water was allowed to flow for 1-2 minutes before collecting the samples.

Water samples were taken from many houses, although all came from the same gravity feed system. First, the bottles' gases were evacuated by filling them, then dumping them over the source and refilling them. Lastly, pH and temperature were measured at the study location.

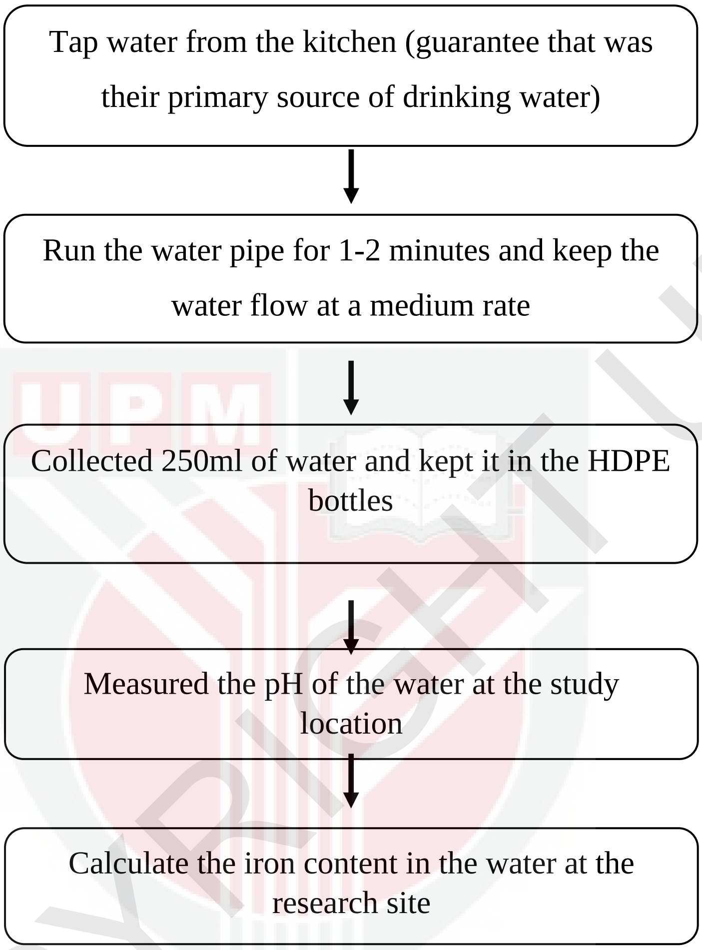

Figure 3.5: Flowchart shows of water sampling process

(Source: Ghosh et al., 2020)

3.7 Quality Assurances (QA)

According to Adeniyi et al. (2016), every day, all of the equipment was calibrated with standard solutions:

i. Both blank and previously spiked water samples were analyzed to ensure quality. One blank in each batch was assessed for contamination potential.
ii. Collection of samples (Field measurements, bottle labelling, proformas, preservation, treatment, and transportation are all covered)
iii. Equipment maintenance. Regular laboratory equipment maintenance is critical for performing controlled analysis on water samples.
iv. Validation, reduction, and reporting of data procedures for calibration: The procedure for preparing standard solutions and creating a standard curve must be specified in calibration analyses, such as the minimal number of different dilutions of a standard that can be employed, the method detection limit (MDL) and the calibration range.

3.8 Quality Control (QC)

3.8.1 Standard of Practice (SOP) of Equipment

According to Rshydro (2022), the accuracy of the EUTECH Cyberscan pH 310 Series was assured by the Automatic Temperature Compensation (ATC), which produces precision under changing temperatures. The following were the Standard Operating Procedures (SOP) for the Hanna Instruments HI801-02 iris Visible Spectrophotometer.

Element: Iron Wavelength (nm): 525 Cuvette (mm): type 22 mm diameter Range 0.00 to 5.00 mg/L (as Fe)

3.8.2 Calibration

Before they were utilised, all instruments were calibrated before examining water samples, which is Hanna Instruments HI801-02 iris Visible Spectrophotometer and EUTECH Cyberscan pH 310 Series.

3.8.3 Pre-Tests

A pre-test questionnaire was an issue to check people's awareness of the question being asked. Before data collection, 10% of the sample size took the pre-test to ensure that every item asked in the questionnaire was intelligible and could be answered by the respondents. It was carried out voluntarily among the Kampung Ulu Chuai residents.

3.8.4 Sample

Each sampling programmed should include tests and checks to assess data quality. These were standard checks for duplicate samples, blanks, reference samples, and performance audits.

* Blanks were samples of clean, uncontaminated water. Blanks were used to identifying contamination in the field or laboratory since they contain no chemical being measured. The presence of a positive chemical concentration in a blank indicates that there is a contamination source somewhere in the method.

3.9 Data analysis

Data analysis was conducted using SPSS version 28.0. Descriptive analysis was performed to provide raw and essential statistical data on the demographic characteristics of respondents as well as iron levels in drinking water. The data were presented as mean, median, variance, standard deviation, interquartile range, and maximum and minimum values.

All continuous variables were tested for normality using Kolmogorov-Smirnov statistics. After that, the data was evaluated in two steps. The first step is to conduct a univariate analysis. The hypothesis was then tested using bivariate analysis, separated into two parts: statistically significant difference testing and relationship or association testing.

Table 3.1: Statistical analysis that was used

No	Specific Objectives	Statistical Analysis
1	To determine iron level and pH level of gravity feed system water samples.	Descriptive analysis Parametric test: mean, standard deviation (SD) Non-parametric test: Median and Interquatile range (IQR)
2	To determine the relationship between iron levels with pH level of gravity feed system water samples	Parametric test: Pearson Correlation Non-parametric test: Spearman Correlation
3	To determine whether there is difference between iron level of gravity feed system water samples in Sungai Mas Village, Sungai Lembing with acceptable Malaysia standard of iron in drinking water.	Parametric test: One sample T-test Non-parametric test: Sign test
4	To determine the health risk among study population of indigenous people in Sungai Mas Village, Sungai Lembing from ingesting iron in drinking water from gravity feed system by calculating Hazard Quotient (HQ).	Descriptive analysis Parametric test: mean, standard deviation (SD) Non-parametric test: Median and interquartile range (IQR)

3.10 Health Risk Assessment

Persons who consume heavy metals from groundwater in their daily lives may undergo health risk assessments to identify potential health effects (Huang et al.,2015).

According to the Division of Toxicants and as recommended by the United States Environmental Protection Agency (USEPA), Fe is not a carcinogen. Because there are only few pathways in this study, only oral intake channel was considered danger to human health, which is from drinking water containing Fe (Huang et al., 2015). Based on the study by Ghosh et al. (2020), population was exposed to iron in water via ingestion. According to the US EPA division of toxicants, iron is non-carcinogenic. Therefore, the hazard quotient (HQ) is used to quantify the non-carcinogenic danger of iron ingestion to human health:

$$\text{Eq (1): } HQ = CDI / RfD$$

$$\text{Eq(2) : } CDI = C \times IR \times EF \times ED / BW \times AT$$

where RfD (mg/kg/day) is the US EPA's recommended iron dosage (0.7 mg/kg/day for iron). The chronic daily iron consumption (mg/kg/day) is determined using C which is the iron concentration in groundwater (mg/L), IR is the human water ingestion rate in litres per day (1.684 litres per day for adults), ED is the exposure duration in years (35 years for adults), EF is the exposure frequency in days/year (365 days for adults), BW is (58.417 kg for adults), AT stands for average time. AT denotes the average time (AT = 365 ED(d)). The substance's non-carcinogenic effects are insignificant if the HQ score is less than one.

3.10 Research Flowchart

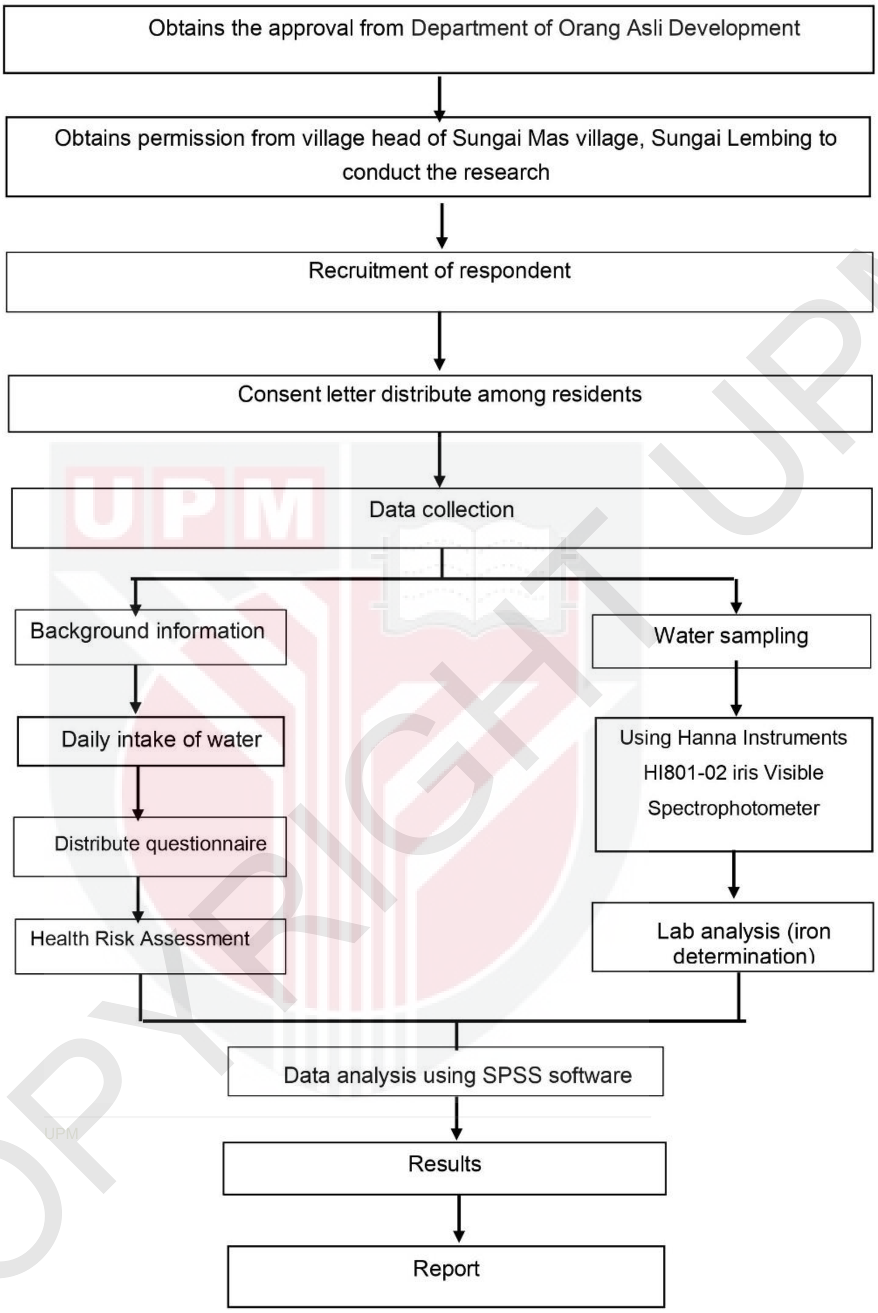

Figure 3.6: Process of research.

3.11Ethical Considerations

Working on a research project required the researcher to acquire authorization from the university's ethics committee, which was one of the requirements. The researcher begins the study project and data collecting after receiving clearance from the Universiti Putra Malaysia (UPM) Ethical Committee and consent from the Department of Orang Asli Development (JAKOA). After getting clearance from the Ethics Committee for Research Involving Human Subjects (JKEUPM) (JKEUPM-2022-405), the study and data collecting begins. Permission was acquired from the householders before conducting the survey, and the study's aim was explained to the respondents. Respondents signed a consent form, and their data was kept confidential.

3.12 Limitations of study

There are a few limitations in this study. Firstly, recall bias. The risk assessment was limited to iron levels in the gravity feed system. It did not consider other factors, such as occupational or environmental hazards. No biological samples were obtained from the study participants to assess their bodies' accurate iron content.

Furthermore, iron bioaccessibility in groundwater was not assessed, making it impossible to determine actual iron exposure. Bioaccessibility is the quantity of an eaten nutrient available for absorption in the stomach after digestion. It can be assessed using solubility, realizability, or gastrointestinal models.

CHAPTER 4

RESULTS

Overall, there were no health risks for individuals in the study region due to the low health index values. However, specific populations with high Fe levels in groundwater necessitate scientific investigation and the implementation of suitable treatments (Huang et al.,2015).

According to the author observations, the iron does not exceed the limit. However, if the iron is inadequate, it may have a few detrimental health consequences. Iron is a secondary or cosmetic contaminant, even without health risks. Iron is also necessary for health because it helps the blood transport oxygen.

4.1 Socio-Demographic Information

According to Table 4.1, there were a total of 104 respondents. They were females (59 respondents – 56.7 %), while the remainder were males (45 respondents – 43.3 %).

Table 4.1: Number of male and female respondents (N=104)

Gender	Frequency	Percent (%)
Male	45	43.3
Female	59	56.7
Total	104	100

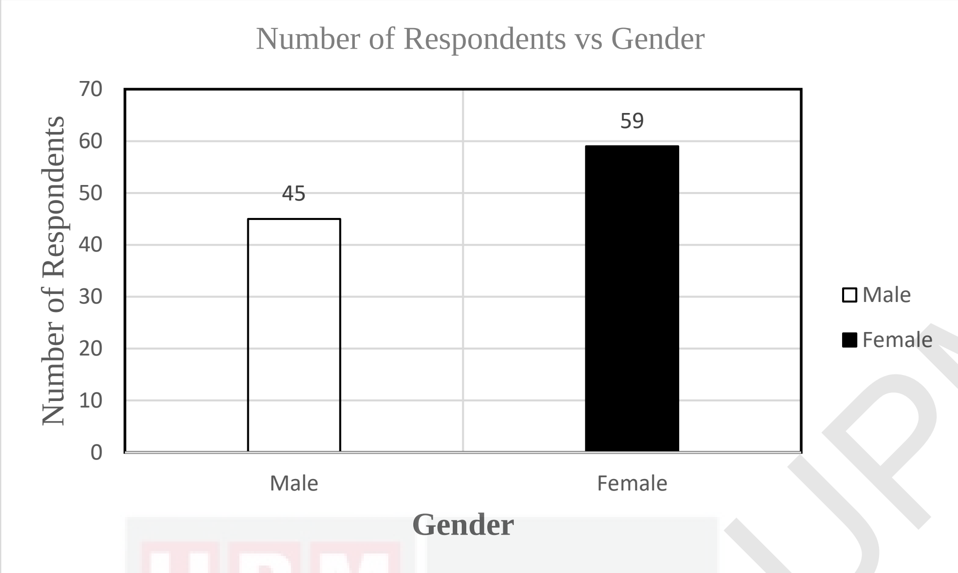

Figure 4.1: Data for male and female respondents

Tables 4.2 and 4.3 correspond to the age and water consumption of the source of iron (tap water). Table 4.2 demonstrates that the respondents aged from 18 to 28 years old (45 respondents-43.3%). This was followed by the 29 to 38 years old group (24 respondents – 23.0 %), 39 to 48 years old (13 respondents – 12.5 %) group, 49 to 58 years old group (15 respondents- 14.5 %) and lastly, 59 years old and above group (7 – 6.7 %).

Table 4.2 : Age of the respondents (N=104)

Age (years old)	Frequency	Percentage (%)
18-28	45	43.3
29-38	24	23.0
39-48	13	12.5
49-58	15	14.5
>58	7	6.7
Total	104	100

The amount of water intake by respondents was between 1 to 3 litres per day (77 respondents -74.0 %). This was followed by 4 to 6 litres (17 respondents- 16.4 %), and the least number of respondents drinking water was more than 7 litres.

Table 4.3: Water intake of drinking water to the source of iron tap water (N=104).

Water Intake (per day) (l)	Frequency	Percentage (%)
1-3	77	74.0
4-6	17	16.4
7-9	5	4.8
>9	5	4.8
Total	104	100

4.2 Iron level and pH level in water samples

As the respondents complied with the inclusion criteria, 104 respondents were picked. The iron concentration varied from 0.030 to 0.55 mg/L, with a median and interquartile range of 0.080±0.030 mg/L. (Table 4.4 and Figure 4.4).

Table 4.4: Levels of iron (N=104)

Parameter	Range (mg/L)	Median (mg/L)	±IQR
Iron in drinking water	0.030 -0.550	0.080	0.030

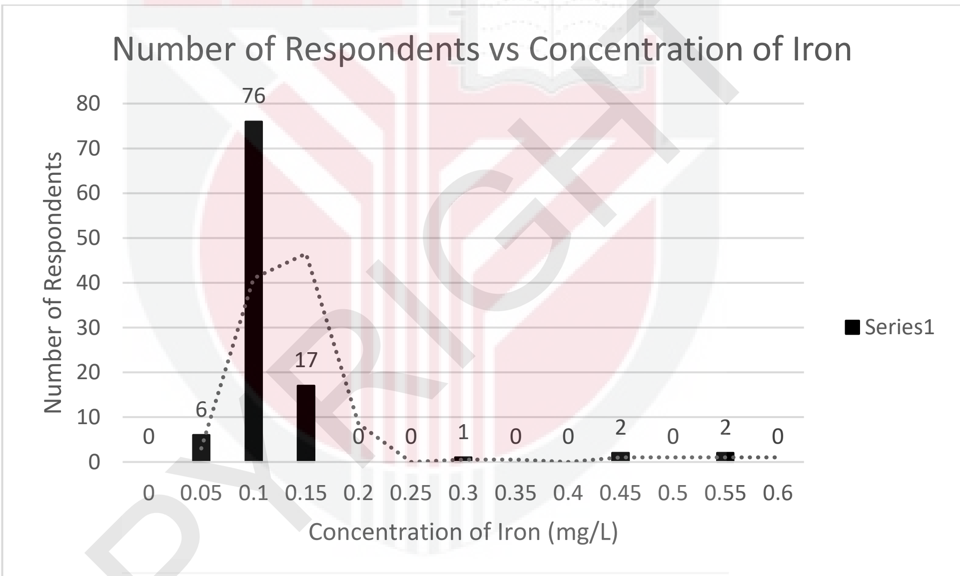

Figure 4.2: The distribution of iron levels in drinking water

The pH level for water samples in Sungai Mas Village, Sungai Lembing, Kuantan was also measured from 7.60 to 9.08. The median and IQR value was 7.89 ±0.16.

Table 4.5: Levels of pH (N=104)

Parameter	Range (mg/L)	Median (mg/L)	±IQR
pH in drinking water	7.60 to 9.08	7.89	0.16

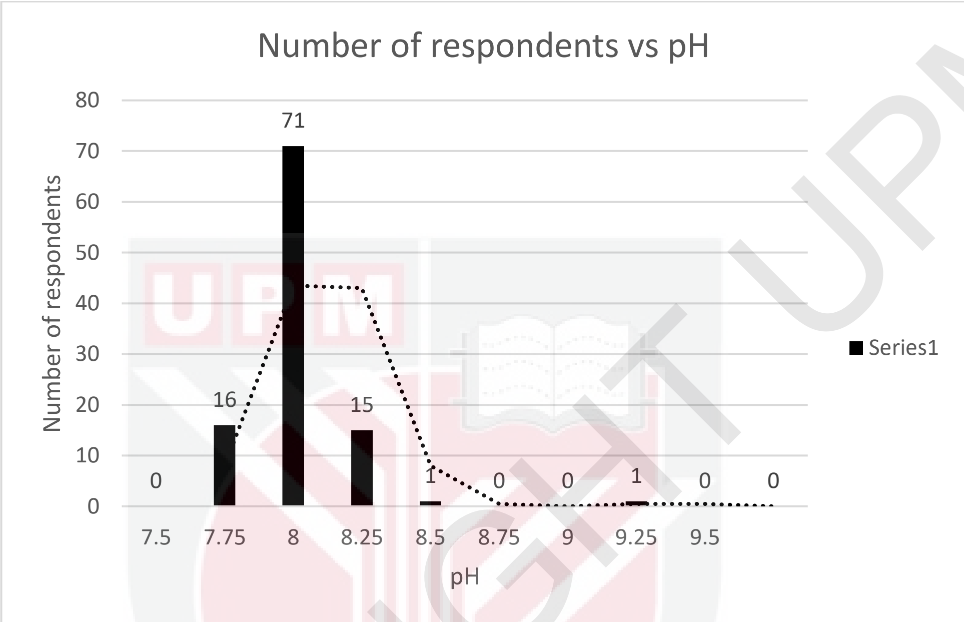

Figure 4.3: The distribution of pH level in drinking water

4.3 Relationship between iron and pH levels in water samples

As previously stated, the iron and pH levels were determined. However, the Kolmogorov-Smirnov test revealed that the iron level in Sungai Mas Village, was not normally distributed, nor was the pH level ($P<0.001$). Consequently, a non-parametric Spearman's correlation test was used to demonstrate the relationship between iron level and pH level (Table 4.6).

There was no relationship between iron and pH since the significant p-value is >0.05. Spearman's rho was used since the data was not normally distributed.

Table 4.6: Spearman's rho Correlation of iron level and pH level

	Correlation coefficient, r	p-value
Iron pH	0.045	0.648

4.4 Difference between iron levels in water samples with NSDWQ

According to the study's findings, the iron levels in drinking water in Sungai Mas Village, ranged from 0.030 mg/L to 0.550 mg/L, with a median value of 0.080 ± 0.070 mg/L. The mean iron levels in drinking water exceeded the National Standard of Drinking Water Quality, NSDWQ, with just a few water samples surpassing the criterion. Four water samples were exceed for the NSDWQ acceptable 0.3mg/L. Figure 4.4 shows that four water samples (3.85%) out of 104 exceeded the drinking water quality requirement.

To compare the iron concentration in drinking water from Sungai Mas Village, with NSDWQ, a non-parametric test (one-sample t-test/sign test) with a reference value of 0.3 mg/L was utilised.

One sample Wilcoxon signed rank test

Table 4.7: Hypothesis of iron with National Standard of Drinking Water Quality, NSDWQ

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The median of iron equals .300.	One-Sample Wilcoxon Signed Rank Test	.000	Reject the null hypothesis.

a. The significance level is .050.

b. Asymptotic significance is displayed.

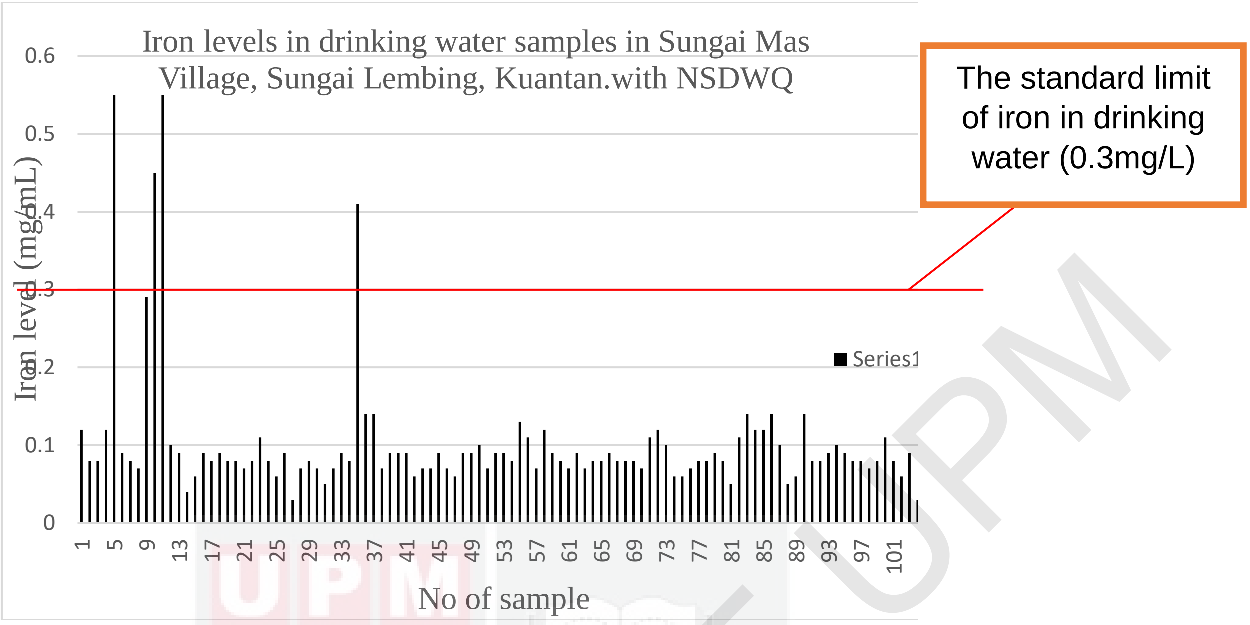

Figure 4.4 : The comparison of iron concentration with the National Standard of Drinking Water Quality, NSDWQ (0.3 mg/mL)

4.5 Respondents' Chronic Daily Intake (CDI)

Chronic Daily Intake (CDI) was computed for each respondent using their actual Daily Intake (DI) and Body Weight (BW), described in Chapter 3. Respondents CDI ranged between 1.967x10-4 mgday-1kg-1 to 4.681x10-3 mgday-1kg-1. CDI from the respondents investigated was median ± IQR 2.230 x10-3 ± 2.078 x 10-3 day-1 kg- respectively. The CDI distributions is presented Figure 4.5.

Table 4.8: Levels of CDI (N=104)

Parameter	Range (mg/L)	Median (mg/L)	±IQR
CDI	1.967x10-4 to 4.681x10-3	2.230×10^{-3}	2.078×10^{-3}

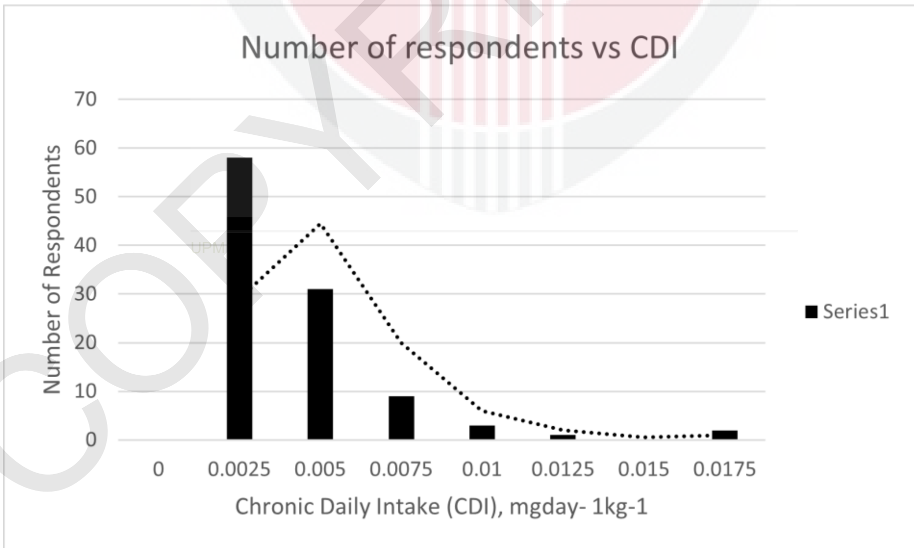

Figure 4.5: The distribution of CDI in drinking water

4.6 Respondents' Hazard Quotient (HQ)

Each respondent's Hazard Quotient (HQ) was calculated using formula in Chapter 3. The computed minimum HQ was 2.810x10-4 mg/L, and the highest was 0.110 mg/L. The median ± IQR HQ of Sungai Mas Village, Sungai Lembing, Kuantan respondents were 3.186x10-3 ± 2.968 X 10-3, respectively. The HQ of all respondents is shown to be less than 1 in Figure 4.6.

Table 4.9: Levels of HQ (N=104)

Parameter	Range (mg/L)	Median (mg/L)	±IQR
HQ	2.810x10-4 to 0.110	3.186×10^{-3}	2.968×10^{-3}

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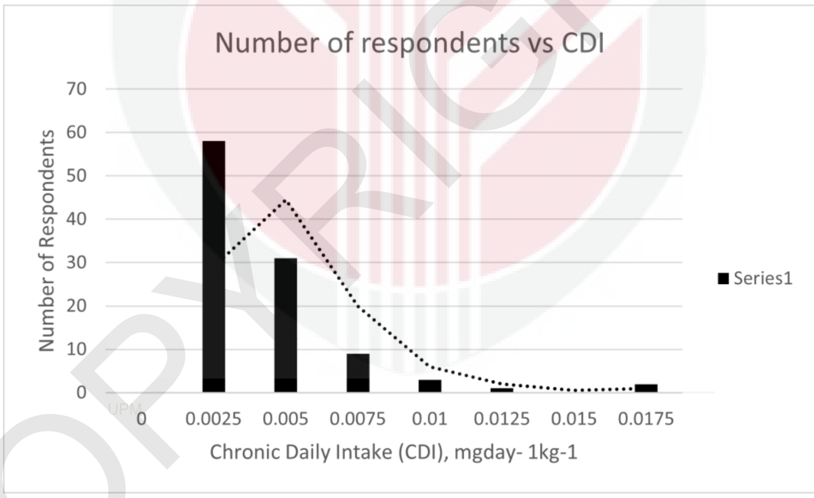

Figure 4.6: The distribution of HQ in drinking water

CHAPTER 5

DISCUSSION

5.1 Iron level and pH level in water samples

Fe levels in drinking water varied from 0.030 – 0.550 mg/L, with a median and IQR of 0.080 ± 0.030 mg/L at Sungai Mas Village, Sungai Lembing, Kuantan. Table 4.4 displays the range and median ± IQR for iron levels. The mean Fe level in Sungai Mas Village, Sungai Lembing, Kuantan, does not exceed the Ministry of Health's upper safe limit (0.3 mg/L) for NSDWQ.

Iron in the water system is present due to rain falling on the land surface and water leaking through soil containing iron. In rare cases, iron might be caused by corrosion of iron or steel well casings or water pipes. When subjected to water and oxygen, iron minerals in water rust and discolour plumbing fixtures and clothing in the same way as iron in a metal pail rusts (Minnesota Department of Health,2022).

According to Kamble (2020), the standard highest iron concentration in Ballarpur, India, is 18.213 mg/L and 0.081 mg/L in Gunjewahi, India. The greatest concentration of groundwater iron is found in Ballarpur in India (3.825 mg/L), followed by Gondpipari in India (3.548 mg/L) and Dabgaon (Tukum) in India (3.084 mg/L). Ballarpur, India, has the highest groundwater iron content in winter and summer. In addition, the Fe concentration in drinking water in Islamabad, Pakistan was 0.616 mg/l.

According to Ghosh et al. (2020), the average (minimum, maximum) iron concentration (mg/L) in Jashore, Bangladesh, was 2.81. (0.027, 10.5). The iron (Fe) concentration in water, soil, and plant samples was measured by Khan et al. (2013). The Fe contents in tap and sewage water were determined to be 0.090 and 0.115 mg/L, respectively.

The pH of water was often considered an essential measure (Kamble, 2020). Many studies have revealed that pH influences heavy metal precipitation and dissolution processes in sediments. In five locations, the pH of the tap water varied a little, ranging from 7.3 to 8.0. Tap water had a median Fe level of 0.0515 mg/mL.

5.2 Relationship between iron and pH levels in water samples

As demonstrated in Table 4.6, there was no relationship between the iron and pH levels of water samples from Sungai Mas Village, ($r=0.045$, $p>0.05$). Finally, the pH level in Sungai Mas Village, does not impact iron solubility in water. It is because soluble iron remains in the treated water as opposed to insoluble iron, which may be removed following the coagulation and flocculation processes of water treatment. It was contradicted with Ibrahim Mohammed Ibrahim, N. (2016) statement, the link between pH and iron levels shows that iron concentration increases with increasing pH values. Conversely, lower pH values below 6.5 tend to maintain iron deposits in solutions, causing corrosion difficulties.

5.3 Difference between iron levels in water samples and NSDWQ

The average iron concentration in drinking water was lower than the NSDWQ allowable values. Four water samples exceeded the NSDWQ maximum permissible limit of 0.3 mg/L. Iron levels in gravity feed system water from Sungai Mas Village, Sungai Lembing, Kuantan, and NSDWQ differed significantly. The non-parametric one-sample t-test, also known as the one-sample Wilcoxon signed rank test was done to see this difference.

In winter (47.100 mg/L), summer (3.825 mg/L), and post-monsoon (4.022 mg/L), groundwater iron concentrations are all high (Merrill et al., 2010). Several sample spots in India have iron levels that exceed the permitted limit, in agreement with (Chetia&Borah, 2008). According to Muhammad et al. (2010), 49% of water samples out of 85 samples exceeded limits which the sample location in Pakistan.

5.4 Respondents' Chronic Daily Intake (CDI) and Hazard Quotient (HQ)

Several factors, including iron levels in water and body weight, might influence respondents' CDI. The CDI of the respondents was calculated using these data. According to the findings of this study, the CDI of respondents from Sungai Mas Village, Sungai Lembing, Kuantan varied from 1.967×10^{-4} mg/kg/day to 4.681×10^{-3} mg/kg/day. The iron Reference Dose (Rfd) of 0.7 mg/kg/day was lower than the CDI of the study participants.

This was primarily due to low iron levels in drinking water. Iron levels were the most crucial contributing component in the CDI equation, rather than other factors such as respondents' body weight and length of exposure to iron in drinking water.

The HQ was used to assess respondents' risk of iron exposure in Sungai Mas Village, Sungai Lembing, Kuantan. A HQ number of less than one suggests an improbable likelihood of harmful health consequences. However, a HQ value more than one indicates a worry about harmful health impacts or the need for additional research.

According to this study, the HQ for Sungai Mas Village, Sungai Lembing, Kuantan respondents varied from 2.810×10^{-4}mg/L, and the highest was 0.110 mg/L. Because the respondents' HQ mean was less than one, they were not in danger of iron exposure. Therefore, due to low CDI values, the respondent's HQ mean was less than 1. According to Liu et al. (2019), all studied components had HQ values well below one, suggesting that water intake posed minor non-carcinogenic risks to occupants of adults and children.

According to Kamble (2020), the CDI was 1.940 mg/kg/day for iron, which was much higher than this research. In northern Pakistan, the hazard quotient value for iron from oral ingestion was more than one (Begum et al., 2015). According to Huang et al. (2015), residents' health may be affected if they ingest groundwater with a greater iron concentration. Seasonal influences on iron distribution were discovered using WHO, JECFA, and IOM guidelines.

According to Ghosh (2020), simple oral consumption of iron through drinking tube well water was examined for assessing people's health risks. The findings of the hazard quotient (HQ) are displayed. The median HQ iron level was 0.161, and the interquartile range was 0.063 to 0.576 in adults.

CHAPTER 6

CONCLUSION

Mean iron levels in Sungai Mas Village, Sungai Lembing, Kuantan did not exceed the NSDWQ upper safe maximum value of 0.3 mg/L. There was no relationship between iron levels and pH levels.

Furthermore, the HQ value was less than one, suggesting that the danger of iron exposure in drinking water was lower than an acceptable level. The iron in drinking water in this study was not influenced. So there are no carcinogenic effects on the community in Sungai Mas Village, Sungai Lembing.

RECOMMENDATION

Since four samples (3.846 %) are over the limit, NSDWQ breaches in Sungai Mas Village, Sungai Lembing, Kuantan, additional action is required to minimize the iron content in drinking water by considering water treatment authority Malaysia to provide safer treated water for the community. In addition, a monitoring program and health education should be implemented in regions where drinking water is likely to be contaminated with iron, such as mining zones. To reduce pollution, it is advised that a water filtration system be used.

Health authorities, such as the Ministry of Health (MOH), must survey the iron content of drinking water regularly tested to ensure that the water being supplied to the public meets the drinking water standards. Take action, whether immediately or as soon as possible if the level of iron exceeds, to address this issue because an increase in iron levels can cause health problems such as Parkinson's disease, Huntington's disease, cardiovascular disease, type 2 diabetes, pigmentation changes, Alzheimer's disease, renal, hepatic, respiratory, and neurological disorders are all possibilities (Ghosh et al., 2020).

In addition, heavy metals in drinking water may be analyzed using biomarkers such as blood, urine, hair, and nails to obtain more accurate results. However, HRA applicability in heavy metal ingestion studies in Malaysia is relatively limited. Nevertheless, HRA is crucial to include in drinking water studies because it may be used to quantify the potential for unfavorable health effects in people. In addition, other researchers may consider doing a health risk assessment for iron in food owing to ingesting more iron than needed.

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APPENDICES I

Sample Size Determination & Photo During Data Collection

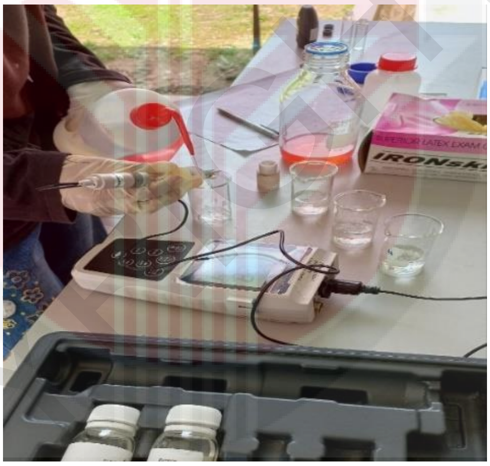
Specific objective	Sample size calculation	References
What is the level of iron in gravity feed system at Sungai Mas Village, Sungai Lembing, Kuantan Pahang?	The sample size is calculated using formula establish by Kirkwood and Sterne (2003): N=p(1-p)/e2,where: N= sample size p= prevalence of high iron in drinking water e= sampling error (0.05) Prevalence= Which is total no of sample that exceed limit / total number of sample taken. =42/85 =0.49 Sample size determination calculation: N=0.49 (1-0.49)/(0.052) =0.49 (0.51)/ (0.0025) =99.96 100 respondents.	The prevalence (p-value) was determined by a study by Muhammad et al. (2010), therefore, the number of respondents in this study is 100 respondents.

Collect water sample and questionnaire from every each of respondent houses

Measure the respondents body weight

Collect water directly from kitchen pipe by using HDPE bottle

Hanna instrument HI801-02 iris Visible Spectrophotometer for iron analysis



EUTECH Cyberscan pH 310 Series for pH

APPENDICES II

Approval from JKEUPM

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

Research title	:	**Health Risk Assessment of Exposure to Iron in Gravity Feed System Water Among Indigenous People in Sungai Mas Village, Sungai Lembing, Kuantan.**
Study Site	:	**Sungai Lembing, Kuantan.**
JKEUPM Ref No.	:	**JKEUPM-2022-405**
Researcher	:	**Nurul Ashikin Bt Mohd Hanafi**
Supervisor	:	**Dr. Shaharuddin Bin Mohd Sham**

Documents received and reviewed with reference to the above study:

1. Ethics Application Form, Version 1 dated 01/06/2022
2. Respondent's Information Sheet /Consent (English), Version 1 dated 01/06/2022
3. Respondent's Information Sheet /Consent (Malay), Version 1 dated 01/06/2022
4. Proposal (English), Version 2 dated 22/06/2022
5. Questionnaire / Interviews (English), Version 1 dated 01/06/2022
6. Questionnaire / Interviews (Malay), Version 1 dated 01/06/2022
7. Curriculum Vitae of:
   a. Dr. Shaharuddin Bin Mohd Sham
   b. Mr. Zaenal Abidin

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

[X] Approved

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

[ ] Disapproved

Please note that the approval is **VALID UNTIL 21 JULY 2023**

Researchers should comply with the following:

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

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

III. <u>Applicable for Clinical Trial Studies and Clinical interventional Studies only:</u> Progress Report has to be submitted to JKEUPM at <u>every 6 months</u> from the date of approval (Form 3.1). Report occurrences of all Serious Adverse Events (SAEs), Suspected Unexpected Serious Adverse Reaction (SUSARs) and Protocol Deviation/ Violation at all JKEUPM approved sites to

APPENDICES III

Approval from JAKOA

KETUA PENGARAH
JABATAN KEMAJUAN ORANG ASLI
(Kementerian Pembangunan Luar Bandar)
Aras 03, West Block, Wisma Golden Eagle Realty
142-C, Jalan Ampang, 50450 Kuala Lumpur
MALAYSIA

JAKOA

Telefon : 03-21610577
: 03-21610994-8(5 talian)
Laman Web : www.jakoa.gov.my

Ruj. Kami : JAKOA.PP.30.032 JLD 53 (19)
Tarikh : 7 Julai 2022

Nurul Ashikin binti Mohd Hanafi
No.20, Lorong SKD 31
Taman PSJ
Perkampungan Sg. Karang Damai
26100 Kuantan
PAHANG

Puan,

KELULUSAN BERSYARAT BAGI MENJALANKAN PENYELIDIKAN / KAJIAN DI PERKAMPUNGAN ORANG ASLI

Dengan hormatnya saya merujuk kepada perkara tersebut di atas.

2. Jabatan ini telah meneliti permohonan puan dan sukacita dimaklumkan bahawa permohonan untuk menjalankan penyelidikan/kajian telah diluluskan. Butiran kelulusan adalah seperti berikut:

Tajuk	:	**Health Risk Assessment Of Exposure To Iron In Gravity Feed System Water Among Indigenous People In Sungai Mas Village**
Tarikh	:	**18 Ogos 2022 – 1 September 2022**
Tempat	:	**Kampung Orang Asli Mas, Kuantan**

3. Puan hendaklah kemukakan laporan pelaksanaan program setelah program selesai dilaksanakan dan puan juga perlu mematuhi syarat-syarat yang ditetapkan di lampiran **Appendix 1** pada Borang Permohonan Penyelidikan/Kajian dan peraturan-peraturan yang telah ditetapkan oleh Kerajaan dalam tempoh kelulusan penyelidikan/kajian. Selain itu, puan hendaklah menghubungi pihak JAKOA Negeri/Daerah sebelum memasuki kampung. Justeru itu, terdapat syarat-syarat tambahan yang perlu dipatuhi seperti di **Lampiran A**.

Lampiran A

1. Hendaklah merujuk dengan JAKOA Negeri/JAKOA Daerah berkaitan terlebih dahulu sebelum menjalankan sebarang program/aktiviti bagi memastikan urusan berjalan dengan lancar dan selamat serta mengelakkan perkara-perkara sensitif berkaitan masyarakat Orang Asli.

2. Responden/peserta hendaklah diberi penerangan yang jelas tentang program/aktiviti yang akan dijalankan dan kenapa mereka terlibat dalam program/aktiviti tersebut;

3. Responden/peserta bersetuju dan penyertaan adalah secara sukarela dan tidak melibatkan implikasi kewangan kepada responden/peserta.

4. Pematuhan sepenuhnya ke atas Prosedur Operasi Standard (SOP) am yang berkuat kuasa serta SOP-SOP berkaitan yang dikeluarkan oleh Kerajaan dari semasa ke semasa;

5. Semua petugas dan urus setia yang terlibat telah pun menerima vaksinasi lengkap dengan mengemukakan Sijil Digital Vaksinasi COVID-19 dan Kad Pengenalan sebagai pembuktian;

6. Petugas dan urus setia perlu menjalani ujian saringan COVID-19 dalam tempoh tiga (3) hari sebelum pelaksanaan program/turun kelapangan menggunakan kit yang diluluskan oleh Kementerian Kesihatan Malaysia. Individu yang didapati positif ujian tersebut **TIDAK DIBENARKAN SAMA SEKALI** menyertai program/ turun ke lapangan;

7. Kapasiti penggunaan dewan adalah 50% daripada kapasiti biasa dan mempunyai sistem vantilasi/pengudaraan berdasarkan garis panduan pengudaraan dan kualiti udara dalaman yang dikeluarkan oleh Jabatan Keselamatan dan Kesihatan Pekerjaan (JKKP);

8. Mematuhi protokol kesihatan yang ditetapkan oleh Kementerian Kesihatan Malaysia (KKM) dan pelaksanaan norma baharu seperti pemeriksaan suhu badan, mengimbas MySejahtera, penjarakan fizikal, penggunaan/penyediaan pensanitasi tangan dan pemakaian pelitup muka **SEPANJANG MASA PROGRAM BERLANGSUNG**; dan

9. Kehadiran calon, penemuduga dan urus setia yang bergejala, sedang dalam Perintah Kawalan Pergerakan Diperketatkan (PKPD), *Person Under Surveillance* (PUS) dan sedang dalam Perintah Kuarantin adalah **TIDAK DIBENARKAN SAMA SEKALI.**

APPENDICES IV

Consent Form & Questionnaire

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

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

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

1. STUDY TITLE :
Health Risk Assessment of Exposure to Iron in Gravity Feed System Water among Indigenous People in Sungai Mas Village, Sungai Lembing, Kuantan

2. INTRODUCTION:

This study is going to determine the health risk rate of exposure to Iron in Gravity Feed Water System among indigenous people in Sungai Mas Village, Sungai Lembing, Kuantan. In addition, this study was conducted to explore the relationship between the health status of the population with the iron content in drinking water. Not only that, this study is also to determine whether there is a difference between the level of iron metal in Gravity Water Supply System with Malaysian standards that have been set in drinking water

3. WHAT WILL YOU HAVE TO DO?

The study was conducted in Sungai Mas Village, Sungai Lembing, Kuantan. Before the distribution of the health risk assessment questionnaire, respondents will be given full information about the study and asked to fill out a consent form(Estimate duration: 10minutes). After that, samples of tap water from the Gravity Feed System Water will be taken from house to house (Estimate duration: 10minutes).
The expected duration for overall data collection is one 20minutes only.No biological samples were taken among the respondents in this study.

4. WHO SHOULD NOT PARTICIPATE IN THE STUDY?

Respondents who used a water filter system at home were excluded in this study.

5. WHAT WILL BE THE BENEFITS OF THE STUDY:

(a) TO YOU AS THE SUBJECT?

They will be more aware of the importance of knowledge about Gravity feed system water and souces of water that can come from physical, chemical, biological and metal pollution.

(b) TO THE INVESTIGATOR?

The main benefit for the researchers in this study is the baseline data of relationship between iron in drinking water and health risk assesements can be generated. In addition, these data can be used as a reference for further studies.

6. WHAT ARE THE POSSIBLE RISKS?

There will be no risk experienced by the respondents that participating in this study.

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

All information and data collected during this study will remain confidential.

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

For inquiries, please contact:

Researcher information

Researcher: Nurul Ashikin bt Mohd Hanafi

Phone number: 011-29402557

E-mel address: 200531@student.upm.edu.my

Supervisor Researcher information

Researcher: Dr Shaharuddin Mohd Sham

Phone number:: *012-3387305*

E-mel address*: shaha@upm.edu.my*

*Please initial here if you have read and understood the contents of this page*______

9. CONSENT

I …………………………………… Identity Card No. …………………………… address……………………………………………………………………………… ……………………... ……………………………………………………..hereby voluntarily agree to take part in the research stated above *(clinical /drug trial/video recording/ focus group/interview-based/ questionnaire-based).

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

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

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

* delete where necessary

Signature ……..…………………… (Respondent)   Signature ……..………………………… (Witness)

Date :…………………………………Name :……………………………….…..

I/C No. :…………………………….…..

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

Date ……..………………………… Signature ……..………………………… (Researcher)

FACULTY OF MEDICINE AND HEALTH SCIENCE QUESTIONNAIRE

The main objective of this study was to determine Health Risk Assessment of Exposure to Iron in Gravity Feed System among Indigenous People in Sungai Mas, Sungai Lembing, Kuantan.

Please answer the question as accurately, honestly, and as completely as possible. All answers are confidential and for research purposes only. Thank you for your participation in this research.

Section A: Socio-demographic factor and information on family background.
Bahagian A: Faktor sosio-demografi dan maklumat latar belakang keluarga.

		Tick (✓)
1.Gender/Jantina	Male/Lelaki	
	Female/Perempuan	
2. 2. Age/Umur	Years/ Tahun	
3. 2. Body weight (BW)/ Berat badan	kg	

Section B: Health status

Bahagian B : Status Kesihatan

		Tick (✓)
1.Do you have any disease stated below?/ Adakah anda mempunyai sebarang penyakit dibawah?	Hemochromatosis	
	Diabetes/Kencing manis	
	Neurodegeneration	
	Parkinson disease/ Penyakit Parkinson	

Section C: Information on drinking water at home

Bahagian C : Maklumat mengenai air minuman di rumah

		Tick (✓)
1.Do you use any water filter at home?/ Adakah anda menggunakan penapis air di rumah?	Yes/ Ya	
	No/Tidak	
2. Water intake/day Pengambilan air/sehari	1-3 litres (ℓ)	
	4-6 litres (ℓ)	
	7-9 litres (ℓ)	
	More than 9 litres (ℓ)	
3. How do you get an acces to drinking water at home? /	Getting drinking water straight from the pipe without any water filter/ Mendapatkan air minuman	

Bagaimanakah anda mendapat akses kepada air minuman di rumah?	terus dari paip tanpa sebarang penapis air.	
	Boiling water from the pipe before drink/ Mendidihkan air dari paip sebelum diminum	
	Getting drinking water by water filters that was installed at the pipe/ Mendapatkan air minuman dengan penapis air yang dipasang pada paip	