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Health Risk From Nitrate Exposure in Gravity Feed System, GFS Water Among Residents of 20th Mile Village, Hulu Langat, Selangor

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ABSTRACT
Nitrate in drinking water, particularly from non-conventional sources like the Gravity Feed System, GFS in Hulu Langat, poses a potential health risk to the population. Therefore, a study is necessary to ensure compliance with the National Standards for Drinking Water Quality and to assess the extent of the resulting non-carcinogenic hazard. A cross-sectional study was conducted to estimate the risk of exposure to nitrate via the Gravity Feed System, GFS water ingestion pathway for the Hulu Langat population. The objective was to examine the health risk associated with exposure to nitrate in the Gravity Feed System, GFS among the population in Hulu Langat, Selangor. A total of 88 respondents with 35 sample water who fulfilled the inclusive criteria were selected in housing areas of Hulu Langat. Questionnaires were administered to determine the information of respondents. Duplicate samples were collected from the kitchen tap using HDPE bottles to determine the nitrate concentration using a HI801-02 Iris Visible Spectrophotometer and the pH using a HI-98129 pH Meter, both from Hanna Instruments. The mean and standard deviation nitrate concentration was 2.4917±1.2610, pH concentration was 7.0680±0.2843 and Hazard Quotient (HQ) was 0.0084±0.0060. All samples did not exceed the National Standard for Drinking Water Quality (NSDWQ), with the maximum result for this study being 5.30 mg/L and was not a significant health concern since all Hazard Quotient (HQ) values were below 1. There was no statistically significant correlation between pH level and nitrate using Pearson correlation test. To conclude, non-carcinogenic risk attributable to nitrate ingestion in Hulu Langat Gravity Feed System, GFS water was negligible.

Keywords: Nitrate, pH, Hazard Quotient (HQ), Non-carcinogenic Risk, Hulu Langat.

INTRODUCTION

Malaysia employs a relatively high absolute amount of water per capita compared to its regional counterparts. The National Water Services Commission (SPAN) (2021) reports that one person utilizes approximately 201 litres of water daily (Federation of Malaysian Consumer Associations (FOMCA), 2021). This high consumption is primarily attributed to the country's hot and humid climate, which necessitates frequent bathing, and a rapidly growing industrial sector that requires substantial water for cooling and production purposes (World Bank Group, 2016). Furthermore, urbanization and changing lifestyles have increased residential water usage due to the adoption of household appliances such as dishwashers and washing machines, coupled with the need for irrigation in parks and urban gardens (United Nations Human Settlements Programme, 2017).

Despite this high demand, Malaysia faces significant challenges in the effective management and utilization of its water resources. Localized water shortages are a recurrent issue, particularly during the dry season, a problem exacerbated by seasonal precipitation variability which leaves some regions with insufficient rainwater (Department of Irrigation and Drainage Malaysia, 2022). Climate change presents additional concerns, increasing the risk of long-term droughts and extreme floods, thereby stressing existing water infrastructure and sources (Intergovernmental Panel on Climate Change, 2024). Compounding these issues is the pervasive problem of water pollution. Industrial effluents and agrochemical discharges, including pesticides and fertilisers, significantly threaten water quality, complicating efforts to ensure the availability of clean, accessible water for human consumption (Department of Environment Malaysia, 2020).

To enhance water security, particularly in underprivileged and rural areas, the Gravity Feed System, GFS has been implemented under the Ministry of Health Malaysia's *Bekalan Air dan Kebersihan Alam Sekeliling (BAKAS)* initiative. The Gravity Feed System, GFS is highly efficient in hilly or mountainous terrain, relying on the force of gravity to transport water without the need for electric pumps (Ministry of Health Malaysia, 2017). This design offers the benefits of low installation and operational costs, making it an economically viable option for remote communities (Roslan M & Mohd F, 2017). However, the reliance of Gravity Feed System, GFS on natural sources and its typically minimal treatment infrastructure make the water sources vulnerable to contamination, especially from surface runoff.

A critical water quality concern in such systems is the presence of nitrates (NO3). While nitrates are essential natural inorganic substances, excessive levels in drinking water pose serious health risks. Once ingested, nitrates can be reduced to nitrites (NO2) by bacterial activity in the gastrointestinal system. Nitrites oxidize hemoglobin, the oxygen-carrying protein in red blood cells, into methemoglobin, leading to a condition called methemoglobinemia (Fewtrell, 2004). This condition reduces the blood's oxygen-carrying capacity, potentially causing symptoms like dyspnea and vertigo, and can be fatal in severe cases, particularly in infants. To safeguard public health, the Malaysian National Standard for Drinking Water Quality (NSDWQ) sets the Maximum Contaminant Level (MCL) for nitrate at 10 mg/L (Ministry of Health Malaysia, 2017). Given the potential for agrochemical runoff and poor sanitation to impact Gravity Feed System, GFS sources, assessing nitrate levels is paramount for public health protection in rural settings.

This study aims to increase knowledge regarding the potential health risks posed by nitrate-contaminated water, specifically focusing on rural communities that rely on the Gravity Feed System, GFS. The research was conducted among respondents and water samples collected from Batu 20, Sungai Lui, Hulu Langat, Selangor, between May and August 2024. The study's findings are intended to support the Hulu Langat community by highlighting the need for improved sanitation practices and advancements in water quality management techniques.

The general objective of this study was to assess the impact of exposure to nitrate in the Gravity Feed System, GFS water on the health of the residents in Hulu Langat, Selangor. The specific objectives were to measure and analyze nitrate levels in the Gravity Feed System, GFS at Hulu Langat, Selangor, in comparison with the NSDWQ, to evaluate the potential non-carcinogenic health risk of high nitrate concentration in the Gravity Feed System, GFS to human health based on the Hazard Quotient (HQ) and to establish the correlation or otherwise of nitrate and pH level with the Gravity Feed System, GFS water samples.

Based on these objectives, the null hypotheses were formulated for testing. Firstly, there is no significant difference between the mean nitrate concentrations in the Gravity Feed System, GFS water samples and the NSDWQ standard of 10 mg/L. Secondly, the exposure to nitrate in the Gravity Feed System, GFS water does not pose a significant non-carcinogenic health risk to the consumers (HQ≤1). Thirdly, there is no significant correlation between nitrate and pH levels in the Gravity Feed System, GFS water samples.

METHOD

Research design

A quantitative research approach was employed to analyze the health impact of nitrate on the population using the Gravity Feed System, GFS water in Hulu Langat. Cross-sectional study approach was used to determine the health impacts of the population exposed to nitrates in the Hulu Langat Gravity Feed System, GFS. This research was aimed to assess the risk from nitrate consumption in rural areas by examining nitrate levels in the Gravity Feed System, GFS of Hulu Langat, as shown in Figure 1. The Gravity Feed System, GFS is a common source of potable water for several communities in Hulu Langat, Selangor, particularly in the rural areas. This research seeks to evaluate the health impacts of using water from this system by surveying the residents.

Study Population

The research population included males and females aged 18 and older who are live long residences in Hulu Langat, Selangor, consuming only the Gravity Feed System, GFS water as their primary drinking water source. Crucially, in epidemiological studies, the findings underlined that residence length helps to capture consistent environmental exposure and behavior patterns, which makes it more accurate. The research also only includes individuals who satisfy these criteria.

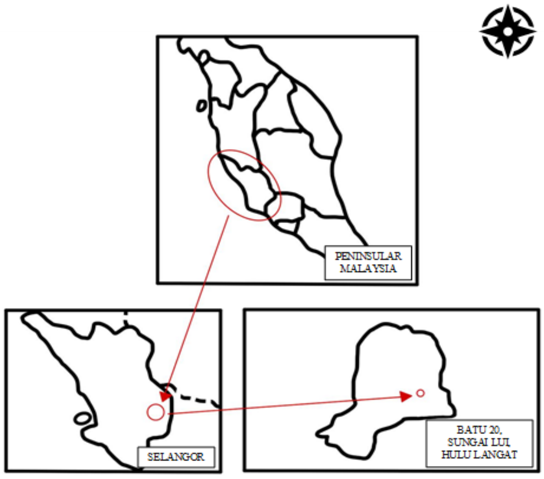

Figure 1
Map of Location

Sampling Units

Before participants were selected, the sample unit was screened according to inclusion and exclusion criteria. An interview was conducted to assess the respondent's eligibility.

Sample Size

A single-proportion approach to determine the sample size necessary for evaluating the effects of nitrate exposure on human health was used as shown in Equation 2.1 (Kirkwood & Sterne, 2003).

Sample size, n = (π(1-π))/e^2

Where:
n = sample size
π = proportion (0.2692) (Azriq, 2024)
e = required size of standard error (0.05)

Sample size, n = (0.2692(1-0.2692))/(0.05)^2

= 78.6925 ≈ 79

Based on Equation 2.2, the overall sample size, when rounded, consists of about 79 respondents.

Sampling Methods

The research commenced upon obtaining ethical approval from the Ethics Committee for Research Involving Human Subjects (JKEUPM).

Table 1
Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
A live long residence in Hulu Langat, Selangor.	Use a water filtering system.
The respondent should be more than 18 years old.	
A Gravity Feed System, GFS is used as the primary source of drinking water.	

Source: Processed Data

To ensure spatial coverage across the study area and adequate water quality representation, 35 unique household taps were selected as distinct sampling points. Duplicate water bottles were collected per site (tap) for quality control. The site selection strategy was implemented using a convenience sampling approach but ensured coverage across different sub-hamlets/local zones served by the Gravity Feed System, GFS, aiming to capture potential variability in contamination due to elevation or proximity to potential pollution sources.

A customized questionnaire was used to gather data from the study participants. A total of 88 respondents were successfully surveyed. Multiple eligible respondents (≥18 years old) could be interviewed from a single sampled household/compound (one of the 35 water sampling points), provided they met all the inclusion criteria. This approach acknowledges the distinction between the 35 physical water samples collected for chemical analysis and the 88 surveyed respondents used for epidemiological data.

The 88 respondents provided consent for the collection of a water sample from their household tap. Approximately 250 milliliters of Gravity Feed System, GFS water were collected from each of the 35 unique household taps. The water samples were immediately analyzed on-site using the HI801-02 Iris Visible Spectrophotometer for nitrate concentrations and the HI-98129 pH Meter (Hanna Instruments, 2024) for pH level. All data collection, including the interview with the respondent and the water sampling, took approximately five to ten minutes per household.

Study Instruments

Questionnaire

The study used a previously established approach for baseline, descriptive and temporal activity assessments in the National Human Exposure Assessment Survey (NHEXAS). It has been tailored for this particular research setting. This tool enables users of the Gravity Feed System, GFS and other water sources to compare their baseline nitrate levels. Furthermore, by using the Gravity Feed System, GFS to quantify the water consumed, the researchers can anticipate the potential nitrate intake.

For clarification, the questionnaire was conducted in Malay and the researcher assisted respondents in completing it. The questionnaire had four components designated as appendices. The first part is the respondents' information, including age, gender and weight. The second part provides information on water usage, such as water intake and water quality satisfaction. The third part is information on the housing environment, including agricultural, septic tanks and waste disposal. The final part provides information on the health and concentration of pH and nitrate.

Body Weight

A digital scale measures the respondents' body weight. Digital scales, renowned for their accuracy, are preferred over analogue scales since they may reduce inaccuracies resulting from wear and friction.

Analysis of Nitrate and pH

The HI801-02 Iris Visible Spectrophotometer was used to quantify nitrate levels in water. It is a precision instrument that utilizes visible light absorption to quantify nitrate levels in liquid samples. Light is transmitted through the sample to link absorbance with nitrate concentration and the amount absorbed at a specific wavelength is quantified. This spectrophotometer offers reliable findings, high accuracy and ease of use for measuring nitrate levels in industrial, agricultural and environmental contexts. Its user-friendly interface and compact dimensions make it suitable for field and laboratory applications. The LCD screen displays the measured result. The meter's calibration data convert the raw signal into concentration values (mg/L).

The HI-98129 pH Meter is a compact, portable instrument for measuring the pH of liquids. It has a high-precision pH electrode for accurate, real-time measurements. The meter's intuitive form and distinct display provide quick calibration and precise measurements across many applications, such as laboratory analysis and agricultural water quality evaluation. It is compact, water-resistant and ideal for standard and portable pH monitoring field applications.

Ethical Issues

Ethical approval from the Ethics Committee for Research Involving Human Subjects (JKEUPM) (Approval No.: JKEUPM-2024-384) was secured before any data collection began. Study objectives were clearly explained to all participants and written informed consent was obtained to ensure participation was entirely voluntary with no penalty for withdrawal at any time. To maintain confidentiality, access to the collected private information is strictly restricted to the researcher and supervisors. For data management, all information is de-identified immediately upon collection using unique codes, with the master code list stored separately and securely. All resulting digital data is stored on a password-protected computer and backed up on an encrypted cloud server. At the same time, hard-copy consent forms are kept in a locked cabinet, with all data scheduled for secure destruction or permanent deletion after five years post-publication.

Data Analysis

All collected data were subjected to statistical analysis using IBM's Statistical Package for Social Sciences (SPSS) Version 26. The dataset included categorical socio-demographic information and continuous data such as nitrate concentration, pH level, and the National Standard for Drinking Water Quality (NSDWQ) for nitrate. Initially, residents' socio-demographic information was summarized using descriptive statistics, while continuous variables were summarized using the mean and standard deviation. The primary analysis involved testing whether the site-mean nitrate concentration in the Gravity Feed System, GFS water sample significantly differs from the NSDWQ limit of 10 mg/L using a one-sample t-test. Subsequently, the Estimated Daily Intake (EDI) and the Hazard Quotient (HQ) were computed for each site or individual to quantify the potential non-carcinogenic human health risk. Finally, a correlation test, Pearson (for normal distribution) was conducted to determine the significant relationship between the nitrate concentration and pH level in the water sample.

Operational Definitions

Nitrate and pH

The Hanna nstruments HI801-02 Iris Visible Spectrophotometer and HI-98129 pH Meter were used to assess the nitrate and pH concentration in Gravity Feed System water, GFS.

Gravity Feed System, GFS

Water samples were collected from each respondent using pre-cleaned 250 mL High-Density Polyethylene (HDPE) bottles. Duplicate samples were collected from each house.

Health Risk Assessment

The Estimated Daily Intake (EDI) assesses the health risks linked to nitrate exposure in drinking water. The Hazard Quotient (HQ) calculation is defined as the ratio of the Estimated Daily Intake (EDI) to the Reference Dose (RfD), which is applied to estimating non-cancer health hazards. A numerical value greater than 1 triggers a possible health risk sign, while an HQ less than 1 means the threat to health is still acceptable.

Quality Control

Quality assurance of data used in water research is very crucial as it impacts the credibility of the results. To have credible results in this study, the following steps were taken to improve the quality of the findings in line with quality control. First, similar collection methods were used to eliminate any differences that may influence the nitrate levels and pH of the samples. To ensure that all measurements for tests were accurate, all equipment were calibrated beforehand. Samples were collected at different times throughout the study to validate the results and ascertain that the fluctuations observed were not a result of instrument inconsistencies. Finally, analysis were performed to ensure that the information was accurate and that the conclusions were consistent over time from a statistical perspective.

RESULT

Sociodemographic Data of Respondents

Data was collected in August 2024. A total of 88 individuals from the study area met the inclusion and exclusion criteria. The number of individuals were more than the sample size (79), which makes the data more accurate. A total of 44 (50.00%) male and 44 (50.00%) female participants took part in this study. The weight range of the research population varied from 42.00 kg to 111.00 kg. The mean weight of the respondent was 65.9700, with a standard deviation of 16.3130.

Respondents' ages varied from 18 to over 60. The majority of respondents were aged 18 to 29, whilst the minority were aged 50 to 59. The study included 21 respondents (23.90%) aged 18 to 29, 18 respondents (20.50%) aged 30 to 39, 17 respondents (19.30%) aged 40 to 49, 12 respondents (13.60%) aged 50 to 59 and 20 respondents (22.70%) aged 60 or more.

Nitrate and pH Readings of Water Samples

This research gathered 35 Gravity Feed System, GFS water samples with duplicates for each sampling site. The number of water samples was less than the number of respondents since each sampling site has more than 1 individual who meets the inclusion and exclusion criteria. The mean nitrate concentration for all samples varied from 0.00 mg/L to 5.30 mg/L. The nitrate value had a mean of 2.4917 and a standard deviation of 1.2610.

Additionally, these samples had pH values ranging from 6.51 to 7.67. The mean pH reading was 7.0680 and a standard deviation of 0.2843.

Quantify and Compare Nitrate Concentrations to the National Standard for Drinking Water Quality (NSDWQ)

The first objective of the study was to quantify and contrast the nitrate concentrations against the National Standard for Drinking Water Quality (NSDWQ) using a one-sample test. The p-value is 0.00. The null hypothesis is thus rejected because a p-value below 0.05 is considered statistically significant.

Additionally, Figure 2 illustrates that the nitrate concentration in each sample is within the permissible limit of 10 mg/L established by the National Standard for Drinking Water Quality (NSDWQ). The maximum result for this study was 5.30 mg/L.

Table 2
One-sample Test to quantify and compare nitrate concentrations to the National Standard for Drinking Water Quality (NSDWQ)

One-Sample Test						
	Test Value = 10mg/L					
					95% Confidence Interval of the Difference	
Variables	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Nitrate Reading	-35.23	34	0.00	-7.51	-7.94	-7.08

N=35
Source: Processed Data

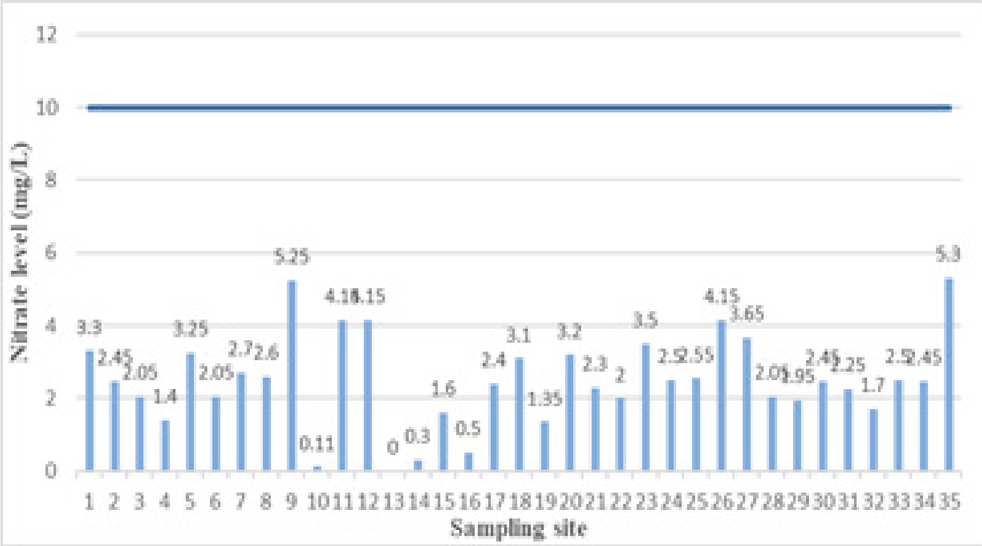

Figure 2
Nitrate concentrations from each sampling site to the National Standard for Drinking Water Quality (NSDWQ) (Syafiq et al., 2024)

Assess the Potential Human Health Risk Associated with Nitrate Concentration by Calculating Hazard Quotient (HQ)

Risk was determined by the use of the Estimated Daily Intake (EDI) and Hazard Quotient (HQ) formulas. An HQ over 1 indicates that respondents' exposure to nitrate in Gravity Feed System, GFS drinking water is a significant health risk. If the Hazard Quotient (HQ) is below 1, the respondents' exposure to nitrate in Gravity Feed System, GFS drinking water does not pose a significant health risk.

Estimated Daily Intake (EDI)

The Estimated Daily Intake (EDI) has been computed in the Literature Review. All samples had values ranging from 0.00 to 0.26. The mean and standard deviation of the Estimated Daily Intake (EDI) were 0.0841±0.0597.

Hazard Quotient (HQ)

The technique outlined in the Literature Review was used to compute the Hazard Quotient (HQ). All samples had values ranging from 0.00 to 0.03. The mean and standard deviation of the Hazard Quotient (HQ) measurement was 0.0084±0.0060. The respondents' exposure to nitrate in Gravity Feed System, GFS drinking water was not a significant health concern since all Hazard Quotient (HQ) values were below 1.

Determine the Significant Relationship Between Nitrate and pH level

The normality test should first evaluate the pH and nitrate concentrations. The Shapiro-Wilk test for significance was applicable due to the sample size being under 50. The p-value for the nitrate level was 0.29, $p > 0.05$. The data is, hence, normally distributed.

Also, the p-value for the pH level was 0.54, $p>0.05$. Therefore, the data was also normally distributed. Given their normal distribution, the Pearson Correlation test assessed the relationship between nitrate and pH levels. This concluded that no statistically significant correlation exists between pH level and nitrate.

Respondent's water usage information

The questionnaire shows that the study population typically drinks between 0.20L and 4.00L of water daily. The respondents' daily water consumption Litres (L) exhibited a mean of 2.0350 and a deviation of 0.9166.

Two respondents (2.30%) expressed dissatisfaction with the water quality, whereas 86 respondents (97.70%) did not. This signifies that the water quality used by the respondents, sourced from the Gravity Feed System, GFS sections of Hulu Langat, is deemed suitable.

Table 3
Pearson Correlation Test to Determine the Significant Relationship Between Nitrate and Ph Level

Variables		Nitrate Reading (mg/L)	pH Reading
Nitrate Reading (mg/L)	Pearson Correlation	1	-0.11
	Sig. (2-tailed)		0.53
	N	35	35
pH Reading	Pearson Correlation	-0.11	1
	Sig. (2-tailed)	0.53	
	N	35	35

N = 35
Source: Processed Data

The results indicated that 11 respondents (12.50%) had used Gravity Feed System, GFS water for 6 to 10 years, while 77 respondents (87.50%) had done so for over 10 years.

Respondent's Living Environment Information

The respondent's living conditions influence the water quality. Examples include an agricultural zone, a septic tank or treatment facility and a waste disposal region. The questionnaire revealed that 63 respondents, or 71.60%, did not reside near an agricultural area. Twenty-three respondents (26.10%) resided next to an agricultural area, whereas two respondents (2.30%) were uncertain about the presence of such an area near their residence.

Forty-seven respondents, or 53.40%, said they did not dispose of waste near their houses. Meanwhile, 41 respondents (46.60%) said that they dispose of waste near their houses. Forty-three respondents (48.90%) said they do not have septic tank in the compound of their house. Forty-three respondents (48.90%) have septic tank in the compound of their house, whereas two respondents (2.30%) were uncertain about the proximity of the septic tank in the compound of their house.

Health Information

Consuming Gravity Feed System, GFS water is linked to several health issues. Examples include shortness of breath, fatigue, vomiting and headaches. Of the respondents, 81 (92.0%) reported no health issues after using the Gravity Feed System, GFS for drinking water, 6 (6.80%) had headaches and 1 (1.10%) reported shortness of breath.

DISCUSSION

Sociodemographic Profile of Respondents

This work evaluated the non-cancer hazard effects of nitrate through the Gravity Feed System, GFS in the Hulu Langat. An exploratory site survey was also carried out to determine potential points for water samples. This study showed that High-Density Polyethylene (HDPE) pipes connected the dwellings in this area to the water supply network. It was from a Gravity Feed System, GFS that collected water from a riverside retention tank. This system channels water from the given tank to the resident's homes. Water supply is provided by a system of pipes for each house.

An analysis of the sociodemographic data yielded that the response distribution of gender was (50.00% of the participants were male while 50.00% were female). The sample included individuals of all ages, from 18 to over 60 years. The age distribution is especially important because it extends from childhood to young adulthood thus enabling the study to estimate risks associated with water quality at different age groups. Twenty-three-point nine zero percent of the total number comprised persons aged 18 to 29 years. The 50–59 age group was the smallest, with 13.60% of the respondents. This distribution is done so that the study findings benefit a large group of people, from youth to the elderly.

The respondents' mean body weight was 65.97 kg, with a minimum of 42.00 kg and a maximum of 111.00 kg. The change in body weight is quite significant as it sheds light on the impact of personal traits, including body mass, when it comes to the use of reception stations, generally, and its consequential health risks likely caused by nitrate intake. Large body size often means increased consumption of water, which if the water is contaminated with nitrates, leads to the intake of these materials into the body system.

Water Quality Analysis

Water samples were taken in High-Density Polyethylene (HDPE) bottles before the pH and nitrate levels in Hulu Langat drinking water were determined. The bottles were placed in the water supply pipes for the Gravity Feed System, GFS at the kitchen sink. It should also be noted that this sampling technique is relevant to the preceding studies, including the study by Aida et al. (2018). To quantify nitrate levels, the HI801-02 Iris Visible Spectrophotometer was used, and the HI-98129 pH Meter estimated the pH of the samples. Using these instruments from the Hanna device, the National Standard for Drinking Water Quality (NSDWQ) was followed.

Nitrate Concentration

A total of 35 water samples were measured and analyzed for two parameters, pH and nitrate. The mean and standard deviation nitrate concentration was 2.4917±1.2610, lower than NSDWQ-MCL of 10.00 mg/L. The study established that the nitrate concentration ranged between 0.00 mg/L and 5.30 mg/L. This is due to the Gravity Feed System's, GFS location in the forest reserve, far from the human population, agricultural, septic tanks and waste disposal. The actual observation made by the study also showed that there were few health-related consequences of nitrate obtained from this water source. Conversely, in a study by (Roslan M & Mohd F, 2017) investigating the Gravity Feed System, GFS in Bertam Village, nitrate concentrations varied from 5.30 mg/L to 9.50 mg/L across 24 sampling sites. These levels fall short of safe drinking water standards, although higher than those identified in the present study. Similar results were in Kampung Raso, Lundu, Sarawak, where 32 sample sites exhibited a mean nitrate concentration of 7.939 mg/L, fluctuating between 7.51 mg/L and 8.37 mg/L (Benard, 2013). This comparison illustrates that Batu 20, Sungai Lui, Hulu Langat have comparatively low nitrate levels. Other sites with a Gravity Feed System, GFS have elevated readings that remain below permissible limits.

pH Concentration

The mean pH value of the water samples was 7.0680, ranging from 6.51 to 7.67. It reflects natural variations in the water supply resulting from geological composition, decomposition of organic matter, dissolved minerals and pollutants from agricultural or industrial runoff. The World Health Organization advises that drinking water should have a pH ranging from 6.50 to 8.50, which is well within this spectrum (World Health Organization, 2017). According to Roslan & Mohd (2017), the recorded pH levels indicate that the water supply is free from chemical pollutants or fertilizers (Roslan M & Mohd F, 2017). A pH level outside this range in water might result in many environmental and health problems. According to the United States Environmental Protection Agency, a pH below 6.50 indicates acidic water, potentially resulting in nonregulatory abnormalities, respiratory illnesses, and reproductive failure (United States Environmental Protection Agency, 2024). Water would be considered alkaline if the pH exceeds 8.50, potentially damaging aquatic ecosystems, reducing biodiversity, and inhibiting the growth of some organisms. The most important range to be kept under control to protect the environment and humans is the pH range of 6.50 to 8.50. This conclusion supports (Roslan M & Mohd F, 2017)'s study who noted that the pH level of Gravity Feed System, GFS water ranged between 6.80 and 7.20.

Health Risk Assessment

Another important feature of this work was evaluating health risks connected with nitrate consumption through drinking water. The exposure level was assessed by determining each respondent's Estimated Daily Intake (EDI) of nitrates. The Hazard Quotient (HQ), an estimate of possible risk to human health, was then determined using the EDI values. According to general health risk assessment principles, an HQ assigned to a substance should be less than 1 to mean no risk, while any value higher than 1 poses non-carcinogenic risks.

Hazard Quotient (HQ)

The method of determining the values for the participants' HQ is described in the Literature Review of the study. The mean of HQ was obtained as 0.0084, whereas the standard deviation was also equal to 0.0060. Most importantly, all the respondents had an overall HQ below one for nitrate intake from drinking water through the Gravity Feed System, GFS with no evident risk to human health associated with nitrate content. In the cross-sectional study by (Roslan M & Mohd F, 2017), the mean nitrate concentration among all the respondents was 2.51 mg/L, ranging from 1.07 mg/L to 6.58 mg/L for which all the respondents had HQ values < 1.

Association Between pH Levels and Nitrate

Identifying the relationship between nitrate levels and pH was attained in this study because of this. Pearson correlation test shows no significant correlation between nitrate concentrations and pH levels. This means that the two factors can be differentiated and measured as different parameters in evaluating water quality. This is in line with an observation that indicated that the water samples taken from the Gravity Feed System, GFS in Ulu Chuai Village did not show any relationship between the pH and nitrates (Mokhtar et al., 2023). A study in the water of Ajiwa Dam, Nigeria showed a lack of correlation between pH and nitrate concentrations, therefore showing once more how independent these factors can be unrelated (Uduma et al., 2024).

Water Use and Satisfaction Among the Respondents

The mean water intake of the respondents was 2.0350 liters per day. This shows that the Gravity Feed System, GFS is adequate to meet the community's hydration water needs. The local people have a positive attitude to the system, and 97.70% of the people are satisfied with water quality. The survey established that the community has always had faith and relied on Gravity Feed System, GFS water due to the respondents who have been using water from this system for more than 10 years (87.50%). However, a study explained that microbial contamination is far-fetched when water is not treated and safely stored, especially in areas with dilapidating infrastructure or poor maintenance (Fathmawati et al., 2017). Although the concentration of nitrate in this study is low, the chemical aspect of water is safe. This means that the microbial aspect is a factor that needs constant monitoring.

CONCLUSION

This investigation proves that the nitrate concentration in the Gravity Feed System, GFS water at Hulu Langat is within the allowed drinking water limit as specified by the NSDWQ. From this result, one can conclude that the water is safe for consumption without nitrate content. Hence, the nitrate level barely exceeds the maximum contaminant limit of 10 mg/L by a fraction, as reflected by the tabular statistical analysis, which shows that nitrate does not pollute the water quality. The research conclusions are further backed up by the health risk assessments, which show that nitrate content in Gravity Feed System, GFS water poses no health risk. The Hazard Quotient of the water source has always been less than one, implying that it is safe for use with complaints for a long duration and nitrate is not considered a health risk. Furthermore, this analysis provided no evidence that water pH has any relationship with its nitrate level. This means that nitrate ions were relatively stable to pH changes and therefore the two factors could be independently investigated on their contribution to the quality of water. Therefore, it is possible to maintain water quality uniformly without emphasizing either one of these factors or the other. In conclusion, the water in the study area's Gravity Feed System, GFS is as good as safe and of the required quality. Once again, it is crucial to stress that constant surveillance is required if the sustainable utilization and protection of the water supply are to be achieved. Despite offering relevant data on nitrate concentrations in the Hulu Langat Gravity Feed System, GFS water supply, this study has several important limitations. First, the small sample size of 88 respondents from a single village limits the generalizability of the findings to only a fraction of the Hulu Langat district or areas with highly similar environmental and demographic profiles. Second, data collection was restricted to sunny weather conditions due to time constraints, meaning the research could not assess how factors like precipitation and seasonal variations affect nitrate levels and overall water quality and future studies should address this by sampling across different meteorological conditions and seasons. Finally, the reliance on participants' self-reported data introduces the risk of memory bias regarding information like water intake and health status and future research should therefore incorporate more objective data quantification techniques likes water intake records to enhance reliability. Nonetheless, the current findings significantly extend the existing knowledge on water quality in the region and provide a valuable foundation for subsequent research and evaluations.

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