Risk Assessment among the Residents of Kampung Kuala Pansoon, Hulu Langat on Nitrate Intake of Gravity Feed System (GFS)

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Abstract: The objective research to determine the level of nitrate in the gravity feed system and carry out a health risk assessment of nitrate ex- posure among the residents of Kampung Kuala Pansoon, Hulu Langat, Selangor. Set of questionnaires was administered to 95 respondents in Kampung Kualan Pansoon. The nitrate level in the Gravity Feed System was measured using a HI98191 Professional Waterproof Portable pH/ORP/ISE Meter with an at- tached Ion Selective Nitrate Combination Electrode (ISE) HI4113. The Estimated Daily Intake (EDI) was calculated, and the major differences in exposure and overall likelihood of non-carcinogenic health impacts posed by nitrate in drinking water were addressed by using Hazard Quotient (HQ). The mean nitrate concentration obtained was 7.22 mg/L ± 4.97 (SD), which did not exceed the maximum allowed nitrate concentration in drinking water (10 mg/L). However, seven samples of drinking water exceeded the standard level, while 73.1% of the houses' nitrate concentration was at a safe level. The findings of this study indicate that the Gravity Feed System is generally providing safe drinking water to the community of Kampung Kuala Pansoon. While some individual samples exceeded the nitrate standard, the overall mean concentration was within the acceptable range, and the majority of households had safe nitrate levels. Nevertheless, the presence of nitrate levels above the standard in some samples warrants continued monitoring of the Gravity Feed System. Further investigation is recommended to identify potential sources of nitrate contamination and implement targeted mitigation strate gies.

Keywords: Nitrate, Drink of Water, Gravity Feed System

INTRODUCTION

In Malaysia, the government is emphasizing the availability of clean water in both urban and rural regions. To enhance the level of living in rural areas and the quality of the water supply, the Ministry of Rural and Regional Development and the Ministry of Health (MOH) have worked together. MOH is participating in the Rural Water Supply and Sanitation (BAKAS) scheme and implementing the duties appropriately (Mohamed & Fadhil, 2017). The most practical solution for issues with rural water supply is the gravity feed system since it only needs little maintenance and has very low operating expenses. Almost zero to no maintenance is needed when the source is protected from any kind of contamination. The foundation of a gravity feed system is often a modest concrete structure that serves as a dam, elevated above the settlement area on the higher reaches of the stream. Natural forces will utilize pipelines in a gravity flow system to transport water from a stream to the user. This technique works well with streams and rivers that have significant elevation variations that enable the water to migrate by gravity from the input to the user or storage tank. Local considerations will determine the size of the dam, the pipe diameters, and the materials. The decision to build a storage tank in a community will rely on the water supply's capacity in the area as well as the project's financial resources (Mohamed & Fadhil, 2017).

Nitrate oftenly derived from human excrement, fertilizers containing nitrogen, agricultural land and compost which all of them are utilized to improve nutrition. One of the most prevalent water pollutants is nitrate. It is often derived from agricultural land, fertilizers containing nitrogen and compost, and human excrement, all of which are utilized for im- proving nutrition. Nitrate leaching from the actions of humans into groundwater and aquatic habitats causes NO3-N concentrations to rise over the standard amount (10 mg/l). The substance can remain in groundwater for decades and accumulates over time (Moeini & Azhdarpoor, 2021). An excess of nitrate (>45 mg/L) in surface water causes eutrophication and hypoxia of water bodies, as well as a direct hazard to human health. Because nitrate is very mobile and largely comes from non-point source emissions, it is disseminated over a large region via numerous groundwater as well as surface flow routes, making tracing where it comes from challenging (Kim et al., 2023).

Nitrites have a unique biological purpose in humans that involves oxidising functional haemoglobin (Hb) into nonfunctional methaemoglobin (metHb), which impairs hemoglobin's ability to carry oxygen to body tissues. Because there is less oxygen being transported, asphyxia may occur when metHb levels equal or surpass 10% of normal Hb concentrations. Red blood cells in newborns may oxidise from ferrous iron (Fe^{2+}) to ferric iron (Fe^{3+})-containing methaemoglobin (Fewtrell, 2004). Because methemoglobin's ability to carry oxygen in the blood is greatly reduced, this can result in "blue baby syndrome," a potentially fatal illness (Beaudet, 2014). According to a 2006 assessment by the International Agency for Research on Cancer (IARC), ingesting nitrate in circumstances that lead to internal nitrosation is "probably carcinogenic to humans." Nitrosating agents derived from nitrate react with nitrosatable molecules during internal nitrosation to produce N-nitroso compounds (NOC).

METHOD

This was a cross-sectional study conducted in October 2023 among the residents of the Kampung Kuala Pansoon, Hulu Langat in order to determine the health risk assessment of nitrate in the Gravity Feed System (GFS).

1.1 Study Sample and Sampling Method

Study population that was selected in this study was the residents either male or female that are above 18 years old who lived in Kampung Kuala Pansoon. Participants were randomly selected in conducting this study and purposive sampling was used in this study where the respondents are chosen based on the inclusive criteria which was gravity feed system as their main source of drinking water, residential period more than 12 months and residents age more than 18 years old. Exclusive criteria for this study were the residents that use any type of water filtering system at their home.

1.2 Study Instrument

A set of questionnaires containing two sections—Section A and Section B—were distributed to every responder in this study. The NHEXAS-Arizona Study's Baseline, Descriptive, and Time-Activity Questionnaires served as the model for the questionnaire that was used.

1.3 Risk Assessment Calculation

Prior to determine the exposure of respondents to nitrate in drinking water, Estimated Daily Intake (EDI) was calculated with the following equation:

$$EDI = \frac{(C_N \times C_D)}{BW}$$

Equation 1 (Moeini & Azhdarpoor, 2021)

Where :
EDI= Estimated Daily Intake CN= Concentration of Nitrate
CD= Average Daily Consumption of
Potable Water (L/day) BW= Average
Body Weight in The Studied Groups

Finally, the major differences in exposure and overall likelihood of non-carcinogenic health impacts posed by nitrate in drinking water was addressed by using the following equation:

$$HQ = \frac{EDI}{R_F D}$$

Equation 2 (Moeini & Azhdarpoor, 2021)

Where:
HQ= Hazard Quotient
EDI= Estimated Daily Intake
RFD= Reference dose for chronic oral exposure to nitrate

A HQ number larger than one (HQ>1) indicates a considerable risk level. More significant the value, more likely is the pos- sibility of negative non-carcinogenic health effects. According to the US EPA's Integrated Risk Information System (IRIS), the oral reference dose utilized in this study is 1.6 mg/kg/day.

1.4 Quality Control and Quality Assurance

Before collecting drinking water samples, the researcher meticulously donned a pair of gloves to prevent any contaminants from their hands from inadvertently introducing cross-contamination. To ensure the absence of any contaminants or rust from the pipe, the water was continuously drained for approximately a minute. Subsequently, the bottles and their caps were meticulously rinsed three times prior to sample transfer. The bottles were then carefully filled, leaving about 1 to 2 inches of headspace. Notwithstanding, the nitrate electrode, a crucial tool in this endeavor, was meticulously maintained and calibrated before each sampling activity, adhering to the guidelines outlined by the USEPA (2023).

RESULTS

1.1 Socio-Demographic Data and Body Weight Measurement

This study was able to recruit 95 number of respondents. Results in Table 1 showed that among the exposed respond- ents, there were higher percentage of female respondents compared to males. Majority of the respondents (24.2%, n=23) were in the range of 51-60 years old compared to other age groups. For residential period, 31-40 years length of stays marked as the highest percentage (24.3%, n=23). The results of the mean body weight of the respondents were 66.59kg ± 12.54.

Table 1. Shows The Socio-demographic Data of The Respondents

Variabel	N = 95	Percentage (%)
Gender		
Male	43	44.8
Female	52	54.2
Age		
< 20	3	3.2
20-30	21	22.1
31-40	22	23.2
41-50	7	7.4
51-60	23	24.2
61-71	19	20
Residential Periode		
5-10	21	22.1
11-20	10	10.5
21-30	16	16.8
31-40	23	24.2
41-50	3	3.2
51-60	13	13.7
61-70	9	9.5

1.2 Water intake and usage of Gravity Feed System

Based on the questionnaires distributed to the residents of Kampung Kuala Pansoon, Hulu Langat, the highest water con- sumption among the respondents was 2 litters per day, with 44 respondents (46.3%) indicated this consumption level. This was followed by 3 litters per day (n=37, 38.9%), 1 litter per day (n=11, 11.6%), and 4 litters per day (n=3, 3.2%). Notably, all 95 respondents (100%) used tap water as their primary source of drinking water. The Gravity Feed System (GFS) serves as the primary source of raw water for these households.

Table 2. The Information on Water Intake and Usage of Gravity Feed System (GFS) Among The Respondents

Variable	N = 95	Percentage (%)
Water Consumtion (Liters)		
1	11	11.6
2	44	46.3
3	37	36.9
4	3	3.2
Ag Tap water as main source of drinking water e		
Yes	95	100
No	0	0.0
Usage of water filtration system		
Yes	0	0.0
No	95	100

1.3 Concentration of Nitrate andLlevel of pH in Drinking Water Samples

Based on table 3, mean onitrate concentration indicated 7.22 mg/L with the standard deviation of 4.97. Minimum concentration was 1.15 mg/L and maximum concentration of nitrate was 19.60 mg/L. For pH level in the drinking water samples, mean indicated was 6.00 with standard deviation of 1.15 with minimum level of 4.8 and maximum level of 8.5.

Table 3. The concentration of nitrate and level of pH in drinking water samples

Variable	Mean	SD	Minimum	Maximum
Nitrat concentration (mg/L)	7.22	4.97	1.15	19.60
Ph	6.00	1.15	4.8	8.5

1.4 Correlation between nitrate concentration and level of pH in drinking water samples

Spearman's correlation was used to analyze the correlation between the concentration of nitrate (mg/L) and level of pH because neither variables were not normally distributed. Based on table 4.4, the calculated spearman's coefficient was -0.135 where it indicated negative correlation. Calculated value for p-value was 0.512 where $p>0.05$ that showed there was a significant difference between nitrate concentration (mg/L) with pH level.

Table 4. The Correlation Between Nitrate Concentration and Level of pH in Drinking Water

Variabel	N	Mean	r	p-value
Nitrat Concentration (mg/L) Level of pH	26	7.22 6.00	-0.135	0.512

1.5 Comparison of Nitrate Concentration (mg/L) and pH Level with NSDWQ

One sample Wilcoxon signed ranked test was used to calculate the significant level since the variable for nitrate concentration was not normally distributed. Based on Table 5, significant level for 2-sided test calculated was 0.011. This shows that the p value was between 0.001 and 0.05 where there was significant difference with the standard value of nitrate concentration (10mg/L). The results indicated that there are 7 households' sample that exceeded the standard level and 73.1 % of the houses' nitrate concentration was in the safe level of nitrate concentration while 21 houses (80.1%) below the lower limit of acceptable pH range of NSDWQ.

Table 5. The one-sample Wilcoxon Signed Ranked Test.

Variable	n	Mean	p-value	Decision
Nitrat Concentration (mg/L) Level of pH	26	7.22 6.00	0.011	Rejected the null hypothe sis

1.6 Health Risk Assessment

1.6.1 Estimated Daily Intake (EDI) calculation.

Shows the Estimated Daily Intake (EDI) was calculated to assess the health risk posed by nitrate in drinking water. The mean of the EDI was 0.25 mg/kg/day with the standard deviation of 0.09. The minimum value of EDI was 0.08 mg/kg/day while the maximum was 0.60 mg/kg/day.

Table 6. Estimated Daily Intake (EDI) Calculation

Variabel	n	Mean	SD	Minimum	Maximum
Estimated Daily Intake (EDI) (mg/kg/day)	95	0.25	0.09	0.08	0.60

1.6.2 Hazard Quotient Calculation

Hazard quotient (HQ) was calculated to finally determine the non-carcinogenic health risk assessment of nitrate in drinking water exposure towards the respondents in Kampung Kuala Pansoon. EDI and Reference Dose (RfD) needed to be deter-mined prior to the calculation of HQ. Reference Dose (RfD) for nitrate in drinking water is 1.6 mg/kg/day according to US EPA's Integrated Risk Information System (IRIS). Table 7 shows the calculated HQ value where mean of HQ was 0.15 with standard deviation of 0.06. Minimum value of HQ recorded was 0.05 while maximum was 0.38. Referring to the table 7 shows that all respondents' HQ was less than 1 that shows adverse effects are not prone to happen in the population.

Table 7. The value of Hazard Quotient (HQ) of the Respondents

Hazard Quotient (HQ)	n	Frequency	Percentage (%)	Mean	SD	Minimum	Maximum
HQ < 1	95	95	100	0.15	0.06	0.05	0.38
HQ > 1		0	0				

DISCUSSION

From the socio-demographic data, residents of Kampung Kuala Pansoon, Hulu Langat consist of both genders with multiple range of age groups from 19 years old to 70 years old. Moreover, respondents in this study stayed in this study location for more than five years where they were exposed to available nitrate in drinking water for a long period. Residential stay period is a crucial parameter that needs to be considered. According to the study conducted by Ward et al. (2018), length of time of the respondent at a source of a drinking water is a result of combination of regulatory measurements with questionnaire and supplementary data to further describe each person's distinct nitrate exposure variability. Apart from that, based on the evidence from previous study, health effect (Colorectal Cancer) is four times as much on the group that has been exposed to nitrate for more than 10 years compared to the group who has been exposed less than 10 years (Fathmawati et al.,2017).

Although health effects of nitrate exposure in drinking water (Methemoglobinemia) are more prone to occur to in fants less than 4 months due to the body fluids that three times more than normal adults and easily absorbed condition due to the pH level of their stomachs, methemoglobinemia can also be seen in adults. This is proven by the study by Imani et al. (2019), where the study mentioned that 56.6% (30 respondents) met the criteria of methemoglobinemia (methemoglobin level exceeded 2 percent).

Based on the table 2, all the respondents (95 people/100 %) stated that they used tap water as main source of drinking water apart from domestic usage such as cooking and washing the dishes. Tap water that the respondents consumed are flowed directly from the Gravity Feed System (GFS) collection tank to individual houses by using Poly pipes that were approved by Standard and Industrial Research Institute of Malaysia (SIRIM) that were installed along the river. This indicated that they were potentially exposed to the equal quality of water with the contamination of nitrate available in the drinking water.

Apart from that, all the respondents (95 people/100%) clarified that they did not install any water filtration system at their home. This shows that nitrate contaminants present in the drinking water will totally be exposed to the consumers. Installation of water filtration system will cause an effect towards the measurement of nitrate due to the capability to re- move a percentage of nitrate from the drinking water itself. Reverse osmosis is one of the processes that can carry out the reduction of nitrate level in the drinking water where the water that supplied by the source will go through a semipermeable membrane that acts like a filtering tool that separates nitrate ion and allowing water free from ions to flow through the membrane hence, reducing the nitrate level significantly (Penn State Extension,2022). Reverse Osmosis (RO) unit was installed at a clinic had initial measurement of nitrate in the range of 35 to 45 mg/L in the feed unit and final measurement in the Reverse Osmosis (RO) product unit were in the range of 1.4 to 5.2 mg/L. The percentage of nitrate removal in this study were between 86.7% and 96.7%. This evidence indicated that usage of water filtration system will greatly influence the nitrate exposure in Gravity Feed System (GFS) to the consumer as they are less likely to be affected by the health effects of nitrate exposure in drinking water because the amount of nitrate in the gravity feed system will have high potential to be in a safe level that is below 10 mg/L (NSDWQ,2000).

According to the comparison with the study by Muhammad et al. (2020), the previous study's mean nitrate con- centration recorded at 2.91 mg/L with the standard deviation of 2.57 mg/L. The minimum and maximum nitrate concentration recorded were 0.42 mg/L and 8.78 mg/L. Based on the comparison with another study conducted by Roslan (2017). More comparison was conducted with the study by Shaharuddin et al. (2024), where the mean reading was 4.99 $\pm$ SD 1.37 mg/L (N=48).where the mean of nitrate concentration (N=82) was 1.20 mg/L with the standard deviation of 0.40 mg/L. In addition, another study that was conducted by Bernard (2013) at Kampung Raso, Lundu, Sarawak indicated that the nitrate concentration mean was at 7.939

mg/L with standard deviation of 1.194 mg/L. The minimum and maximum concentration of nitrate were 7.509 to 8.370 mg/L respectively.

The study conducted by Roslan (2017) on the water quality monitoring on Gravity Feed System (GFS) shows that the value of pH in his study were on the range of 6.8 to 7.2. Level of pH are measured immediately (in-situ) onsite soon after water samples being collected in the HDPE bottles. Correlation coefficient for the correlation between the concentration of nitrate and pH level was -0.135. This shows that there is a negative correlation between nitrate concentration in the drinking water and the pH level of drinking water. The result of this is consistent with the previous study that was done by Dadgar (2017) where negative correlation between nitrate and level of pH was observed. Based on the study conducted by Saalidong et al. (2022). In a study by Saalidong et al. (2022), there was a negative correlation between pH and nitrate in surface water ($p<0.05$) but not in ground water. It means that as pH increases, nitrate levels decrease.

Referring to the NDSDWQ of Malaysia, the acceptable limit of nitrate concentration in drinking water needs to be below 10 mg/L. The mean nitrate concentration for this study was 7.22 mg/L which concluded that the value does not surpass the 10 mg/L and was below the maximum limit. Moreover, based on the One-Sample Wilcoxon signed ranked test, the obtained asymptotic significant value (2-sided test) was 0.011 where the decision was rejecting the null hypothesis. This indicated that there was a significant difference between the value of nitrate concentration and the NSDWQ standard. This study is consistent with the previous study conducted by Muhammad et al. (2020) where the mean nitrate concentration (2.56 mg/L) did not exceed the NSDWQ standard limit of nitrate concentration in drinking water (10 mg/L). However, looking at the obtained nitrate concentration from each house as shown in figure 4.5, seven out of twenty-six (26.9%) houses exceeded the NSDWQ standard limit of nitrate concen- tration (10mg/L). These results are consistent with the study conducted by Aida et al. (2018) where 36 (24 percent) of the samples for non-agricultural area exceeded the acceptable limit of nitrate concentration in drinking water (10mg/L).

The condition of Malaysia being a tropical country, rainy condition will allow the leaching of nitrate to increase due to the animal secretions and agricultural activity from nearby area. With the condition of land use of agricultural activities conducted by the indigenous people that stayed near Kampung Kuala Pansoon, Hulu Langat, these activities could be the culprit of the high nitrate concentration obtained during the sampling period. To support this statement, study conducted by Aida (2018) showed the cause of higher nitrate concentration in a locatio was due to deterioration organic substances and anthropological sources. Based on another study conducted by Aida et al. (2018) flowing water additionally has the potential to carry fertilizers and organic substances into the groundwater by precipitation or irrigation.

Even though the mean nitrate concentration at Kampung Kuala Pansoon, Hulu Langat (7.22 mg/L) did not exceed the limit (10mg/L) however, 7 houses exceeded the limit of NSDWQ showed there was a potential risk of health effects of nitrate exposure towards the consumer with the limited filtration of soil matters runoff sipping through the water and nitrate removal method such as reverse osmosis and ion exchange process.

According to NSDWQ for Malaysia, the acceptable range value of pH in water is from 6.5 to 9.0. Compared to this study, the mean pH value was 6.00 with 1.15 standard deviation. Minimum value of pH was 4.8 and maximum value of pH was 8.5. Based on the figure 4.6, 84% of the water sample were below the minimum neutral range pH of drinking water with 8% are in the range of safe level.

Looking at the mean pH of the water samples (6.00), it refers to the condition of the pH in the water was slight- ly acidic compared to the minimum standard range (6.5). According to the United States Environmental Protection Agency (USEPA), a normal standard rain has a pH range from 5.0 to 5.5 which is slightly acidic and, in another condition, where acid rain occurrence due to the presence and blending process with sulfur dioxides or oxides of nitrogen, pH of the rainwater could drop to 4.0 which is acidic and able to causes harm to the aquatic lives. USEPA (2023) suggests that heavy rainfall or periodic acidification increases the concentration of acidic deposits, which the soil is un- able to buffer. Another interaction in the atmosphere where rain drops fused with molecules of carbon dioxide in the atmosphere hence, causing the formation of carbonic acid (H2CO3) (Fondriest, 2013). Based on the weather archive data in Hulu Langat obtained from Meteoblue (2023), it was indicated that on 19, 20 & 21 October, the pre- cipitation was 12 mm, 11 mm & 5 mm respectively. According to the Ministry of Natural Resources, Environment and Climate Change, precipitation in the range of 1-10 mm is considered light rain while precipitation in the range of 11-30 mm indicated as moderate rain.

In this study, mean of the EDI of nitrate exposure in the drinking water was 0.25 mg/kg/day with the standard deviation of 0.09. Minimum EDI calculated was 0.08 mg/kg/day and maximum EDI calculated was 0.60 mg/kg/day. Comparing with the study conducted by Shalyari (2019) the mean EDI of adults from the study (0.1970 mg/kg/day) indicated that the previous's study has the lower mean for EDI for the study. The difference in the EDI calculation was due to the factor of the study having higher mean body weight (78kg) where denominator influenced the final calculation of the EDI besides the average nitration concentration that was lower than this 6.49 mg/L. In another study conducted by Radfard (2018), the calculated EDI for adults was 0.5155 mg/kg/day where the average nitrate intake was relatively high (16.083 mg/kg/day).To further analyze the risk assessment of nitrate exposure in drinking water. The results of the calculations of HQ for the respondents were displayed in table 4.7 where the mean of calculated HQ was 0.15 with standard deviation of 0.06. Overall, all the respondents' HQ calculations were below 1 where it was in an acceptable range and health effects are unlikely to occur towards the consumer. According to a study to determine the nitrate exposure and the health risks associated with it, the HQ for all the respondents remarked below 1 which is consistent to this study with fairly low mean nitrate concentration (2.51 mg/L) with minimum nitrate concentration (1.07mg/L) and maximum nitrate concentration (6.58 mg/L) (Muhammad et al., 2020). In another study conducted at Yantai, China to assess the health risk assessment with nitrate pollution in groundwa ter showed that the mean HQ calculated was above than 1 where calculated HQ equal to 1.43. The value of high HQ was influenced by the concentration of nitrate that was relatively high where the mean nitrate concentration measured was 17.8 mg (Yu et al., 2022). When the value of HQ raises to the value that more than 1, it indicated that the substance (Nitrate) will likely cause an adverse effect towards the consumer's health.

CONCLUSION

The findings of this study indicate that the Gravity Feed System is generally providing safe drinking water to the communi ty of Kampung Kuala Pansoon. While some individual samples exceeded the nitrate standard, the overall mean concentration was within the acceptable range, and the majority of households had safe nitrate levels. Nevertheless, the presence of nitrate levels above the standard in some samples warrants continued monitoring of the Gravity Feed System. Further investigation is recommended to identify potential sources of nitrate contamination and implement targeted mitigation strategies.

Conflict of Interest

The Authors declare that there is no conflict of interest.

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