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HEALTH RISK ASSESSMENT OF NITRATE EXPOSURE ORIGINATING FROM GRAVITY FEED SYSTEM (GFS) WATER: A CROSS-SECTIONAL STUDY IN HULU LANGAT, SELANGOR STATE, MALAYSIA

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ABSTRACT

Background: *This cross-sectional study assessed the health risks of nitrate exposure from the Gravity Feed System (GFS) water in Hulu Langat, Selangor state.*
Method: *The study population consisted of 88 individuals aged 18 and older who have resided in 20th mile Village, Sungai Lui, Hulu Langat, for a long time and used GFS as their primary drinking water source.*
Results: *The mean and standard deviation of nitrate concentration in 35 water samples were 2.49 ± 1.26 mg/L, which is well below the Malaysian National Standard for Drinking Water Quality (NSDWQ) maximum contaminant limit (MCL) of 10.00 mg/L. The mean pH of the water samples was 7.07 ± 0.28, which falls within the recommended range of 6.50 to 8.50 from the World Health Organisation (WHO). The study's Hazard Quotient (HQ) analysis showed a mean of 0.0084 ± 0.0060, with all respondents having an HQ below one, indicating no significant non-carcinogenic health risk from nitrate content in the water. The study found no significant correlation between nitrate concentrations and pH levels.*
Conclusion: *These findings suggest that the GFS water in the study area is safe for consumption in terms of nitrate levels, although continuous monitoring is recommended.*

Keywords: *Nitrate, Gravity Feed System, Health Risk Assessment, Hulu Langat, Water quality*

INTRODUCTION

Access to safe and clean drinking water remains a critical global environmental health challenge, particularly in rural and remote communities. Rapid population growth, agricultural intensification, and land-use changes have increased the vulnerability of surface water sources to chemical contamination, including nitrate leaching from soil and human activities[1–3]. In Malaysia, water security is further strained by high per-capita consumption and localised pollution events, underscoring the need for sustainable and community-based water supply solutions[4]. Within this context, the Gravity Feed System (GFS) has been widely adopted in rural areas as an environmentally friendly, low-energy alternative that relies on gravitational pressure to supply untreated surface water directly to households[5].

Despite its advantages, the quality of GFS water depends heavily on watershed integrity, upstream land use, and environmental protection. Nitrate is one of the most common contaminants found in natural water systems and is influenced by soil composition, organic matter decomposition, and runoff patterns[1–3]. High nitrate levels in drinking water pose significant health risks, including methemoglobinemia in infants and potential long-term carcinogenic effects through endogenous nitrosamine formation[1–3]. To mitigate these risks, the Malaysian National Standard for Drinking Water Quality

(NSDWQ) has set a maximum contaminant limit of 10 mg/L nitrate[6], consistent with international guidelines.

Previous studies in Malaysia have documented variations in nitrate concentrations across rural and peri-urban communities, with contamination risks increasing in areas near agricultural activities or settlements lacking adequate sanitation infrastructure[7,8]. However, limited evidence is available regarding nitrate levels specifically in GFS-dependent communities located within forested catchments, such as Hulu Langat. Understanding nitrate exposure in such settings is critical, as reliance on untreated water combined with long-term daily consumption may influence cumulative health risks.

Given these environmental and public health concerns, this study assessed nitrate concentrations in GFS water and evaluated potential non-carcinogenic health risks among adult residents in Hulu Langat using Hazard Quotient (HQ) analysis. The findings provide baseline evidence for rural water quality surveillance and support policy efforts toward safe and sustainable water resource management.

METHODS

A quantitative, cross-sectional research design was used for this study. The study was conducted in 20th mile Village, Sungai Lui, Hulu Langat, Selangor state, from May to August 2024.

Figure 1. Map of Study Location

The study population consisted of males and females aged 18 and older who were long-term residents of the area and used the GFS as their main source of drinking water. A sample size of 79 respondents was calculated using a single-proportion formula. The final sample included 88 respondents.

Data collection involved a customised questionnaire to gather sociodemographic, water usage, and health information. Water samples were also collected from each respondent's home. The nitrate concentration was measured using a HI801-02 Iris Visible Spectrophotometer, and the pH was measured with a HI-98129 pH Meter, following NSDWQ guidelines.

Health risk was evaluated using the Hazard Quotient (HQ). The Estimated Daily Intake (EDI) of nitrates was first determined using the formula:

$$EDI = \frac{CN \ x \ CD}{BW}$$

where CN is nitrate concentration, CD is daily water consumption, and BW is body weight.

The HQ was then calculated as the ratio of the Estimated Daily Exposure

Dose to the Reference Dose (RfD). This is one method to articulate the HQ formula as Equation 2.2 (Zohre & Abooalfazl, 2021):

$$HQ = \frac{Estimated\ Daily\ Exposure\ Dose\ (\frac{mg}{kg} - day)}{Reference\ Dose\ (RfD)(\frac{mg}{kg} - day)}$$

An HQ of less than 1 indicates no significant non-carcinogenic risk (United States Environmental Protection Agency, 2024).

RESULTS AND DISCUSSION

1. Water Quality Analysis

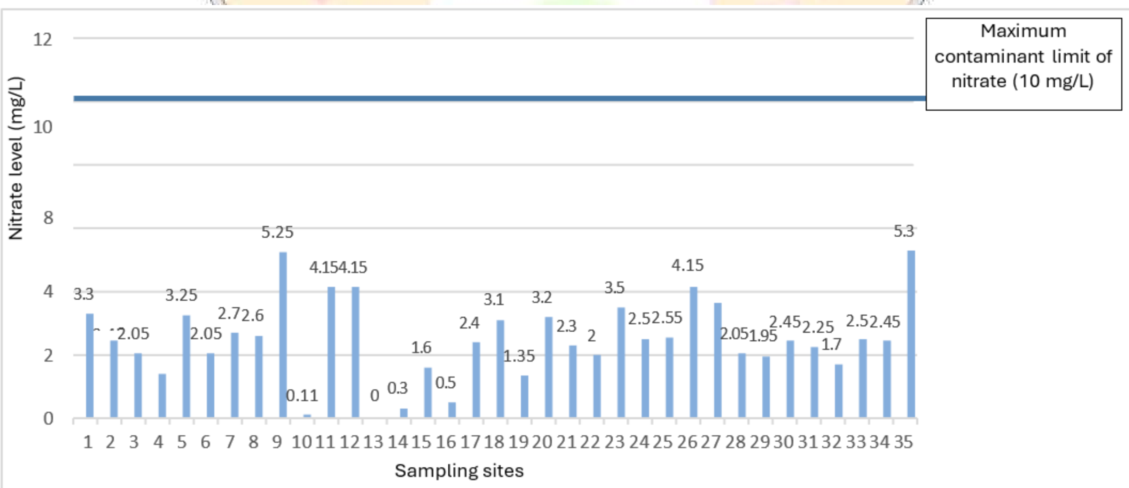
The mean nitrate concentration (2.49 ± 1.26 mg/L) in GFS water was substantially below the NSDWQ threshold of 10 mg/L[6], indicating compliance with national safety standards and suggesting minimal upstream contamination pressure. These findings parallel previous regional assessments reporting that forest-reserve catchments typically exhibit low nitrate concentrations due to limited agricultural or settlement activities[7]. The slightly acidic-to-neutral pH level (7.07 ± 0.28), which conforms to WHO drinking water recommendations[2], further indicates stable hydrochemical conditions and low anthropogenic influence.

The relatively low variability in nitrate values also reflects effective natural filtration by intact forest soils, where organic matter, root systems, and microbial processes facilitate nitrate retention and denitrification[1–3]. This environmental buffering capacity underscores the importance of preserving upstream watershed integrity to sustain water quality in gravity-fed systems.

Table 1. Nitrate and pH Levels in GFS Water Samples

Parameter	Mean ± SD	Min	Max
Nitrate (mg/L)	2.49 ± 1.26	0.00	5.30
pH	7.07 ± 0.28	6.51	7.67

Figure 2. Comparison of GFS Water Nitrate Concentration to NSDWQ Maximum Contaminant Limit



The mean pH of the water samples was 7.07 ± SD 0.28, ranging from 6.51 to 7.67, which falls within the WHO's recommended range for drinking water (World Health Organisation, 2007). This suggests the water is free from significant chemical pollutants (Table 1).

2. Health Risk Assessment

The Hazard Quotient (HQ) values for all respondents were <1 (mean HQ: 0.0084 ± 0.0060), indicating negligible non-carcinogenic health risks from chronic nitrate ingestion. This is consistent with past health risk assessments in rural Malaysian communities demonstrating that nitrate-related risks remain low in areas isolated from intensive agriculture or livestock runoff[7,8].

Low HQ values also reflect stable nitrate inputs over time, considering that 87.5% of respondents had consumed GFS water for more than 10 years. Since the HQ model integrates both exposure dose and reference dose, these results suggest that long-term ingestion of GFS water is unlikely to contribute to adverse health effects, such as methemoglobinemia or nitrosamine-related risks highlighted in the literature[1,3].

Nonetheless, the consistent presence of detectable nitrate levels (even if low) reinforces the need for periodic surveillance, as land-use changes—such as forest clearing or small-scale farming—could rapidly alter nutrient runoff patterns and elevate future health risks.

3. Water Usage and Health Information

Perceptions of water quality were largely positive: 97.7% of respondents reported satisfaction with their water supply. High satisfaction is commonly observed in rural gravity-fed systems, where water is perceived as cleaner due to its natural source and absence of treatment chemicals[5]. The long duration of use (>10 years for most households) reflects strong community trust and reliance on GFS as a primary water source.

Only a small proportion of respondents reported mild symptoms (headache and shortness of breath), and these cannot be attributed to nitrate exposure given the low measured concentrations and HQ values far below 1. More likely, these symptoms reflect other environmental or lifestyle factors not captured in this study.

Importantly, the absence of nitrate-associated health issues supports the premise that forested catchments provide a protective barrier for maintaining safe nitrate levels in rural water systems. However, as rural communities grow and land-use pressures rise, reliance on untreated water continues to pose latent risks. Strengthening community-based watershed protection and implementing routine testing remain essential to sustain long-term water safety.

CONCLUSION

The findings from this investigation confirm that the nitrate concentration in the GFS water in Hulu Langat is well within the NSDWQ limits, and the water is safe for consumption with no associated health risks from nitrate content. There was also no significant correlation found between nitrate levels and pH.

A limitation of this study is the small sample size of 88 respondents from a single village. The data was also collected only during sunny weather, which may not capture variations during the rainy season.

For future studies, it is recommended to expand the sample size to cover a wider area within Hulu Langat and other rural districts in Malaysia. Additionally, long-term monitoring is crucial to ensure the sustained quality of the water supply and to address other potential contaminants, such as microbial pollutants.

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