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NITRATE CONTENT OF BOREHOLE WATER IN AND AROUND NAGONGERA TOWN COUNCIL

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SUPERVISOR

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A RESEARCH REPORT SUBMITTED TO THE DEPARTMENT OF CHEMISTRY IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF DEGREE OF BACHELOR'S IN SCIENCE EDUCATION OF BUSITEMA UNIVERSITY

MAY, 2026

DECLARATION

I, **MALUNDA SOWEDI**, declare that this piece of work is an original product of my own efforts and endeavors without duplication and has never been submitted to any institution whatsoever for any award.

Signature: 

Date: 01/09/2026

APPROVAL

This report has been submitted to the Faculty of Science and Education with the approval of my supervisor.

Supervisor's Name: DR. OWOR ORIKO RICHARD

Signature: .....

Date: 01/09/2026

DEDICATION

This piece of work is dedicated to my whole family for its noble lineage and continued support up to date. May God Almighty bless you for your material, financial and spiritual support during this noble course.

ACKNOWLEDGEMENT

The successful completion of this study was attributed to the help of God Almighty and the efforts and support from various individuals who accorded me maximum cooperation, to whom I am greatly indebted. My innermost and sincere thanks go to my supervisor, **Dr. Owor Oriko Richard**, who wholeheartedly guided me through the study with encouragement, patience and tolerance under all circumstances, providing relevant and necessary technical and academic guidance for the accomplishment of the study.

Further gratitude is extended to all lecturers of the Chemistry Department of Busitema University, and to my fellow course mates and close friends for their encouragement, advice and spirit of teamwork throughout the course. I also owe thanks to all my siblings. Finally, to all those not mentioned here, thank you for your contributions.

MAY THE ALMIGHTY GOD BLESS YOU ALL!

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LIST OF ABBREVIATIONS AND ACRONYMS

UNEP: United Nations Environment Programme

WWDR: World Water Development Report

IARC: International Agency for Research on Cancer

NGOs: Non-Governmental Organizations

N_2: Nitrogen molecule

MCL: Maximum Contaminant Level

M: Molar

HCl: Hydrochloric Acid

$CaCO_3$: Calcium Carbonate

UV-Vis: Ultraviolet-Visible

WHO: World Health Organization

EPA: Environmental Protection Agency

GPS: Global Positioning System

ABSTRACT

In the last few years, borehole water was a very important source of water until the introduction of piped tap water. However, borehole water is still used by the residents of Nagongera town council. This study was carried out to determine the nitrate content of borehole water in and around Nagongera town council. Ten different water samples were randomly collected from boreholes within and around the town council. Each sample was subjected to quantitative analysis using a UV-VIS spectrophotometer to determine the amount of nitrate present.

Using a corrected calibration equation ($Y = 0.267X + 0.0135$, $R^2 = 0.9944$) derived from the standard absorbance data, the nitrate content of the ten samples was found to be 0.6348, 0.6086, 0.6161, 0.5487, 0.6348, 0.6386, 0.6086, 0.5487, 0.6348 and 0.6049 parts per million (ppm) for samples 1 to 10 respectively. The number of pit latrines located near boreholes 1 to 10 were 2, 0, 1, 0, 1, 1, 0, 0, 2 and 1. The results did not show a clear linear relationship with the number of nearby pit latrines, suggesting the influence of other confounding factors that affect nitrate levels in borehole water.

All the concentrations obtained were well below the maximum contaminant level (MCL) for Uganda (50 ppm) and for the United States Environmental Protection Agency (10 ppm). However, the values obtained (0.55 – 0.64 ppm) fall within the 0.21 – 3.0 ppm range that Mueller and Helsel (1996) attribute to combined human and other anthropogenic influences, indicating that some degree of nitrate contamination rather than a purely natural background level is already present in borehole water in and around Nagongera town council.

CHAPTER ONE INTRODUCTION

1.1 Background of the study

According to Chapman (1996), groundwater is the most important component of the hydrological cycle and an important source of potable water in Africa. Groundwater constitutes about two-thirds of the freshwater resources of the world. It also provides a reasonably constant supply for domestic use, livestock and irrigation, and is not likely to dry up under natural conditions, thereby buffering the effects of rainfall variability across seasons (Hamil & Bell, 1986). In many arid and semi-arid areas of Africa, groundwater is a means of coping with water deficiencies where rainfall is scarce or highly seasonal and surface water is extremely limited (David, 2011).

Groundwater depth varies from 30 m to 50 m, though water can be found at depths between 7 and 20 m (Calow et al., 2011). Groundwater is as vulnerable to pollution as surface water, owing to the water table being near the soil surface, overlying layers being permeable, and superficial sources of pollution being numerous (Boutin, 1987; Singh et al., 2012).

World population growth cannot be sustained without access to safe water (Braunstein, 2007). It is therefore important to consider both water quality and quantity in water resource management (Xinghui et al., 2009). Groundwater becomes unsuitable for domestic use when contamination renders it unfit (Holmes, 2007), and contamination of groundwater has increasingly become a serious environmental concern (Akpoveta et al., 2011). Natural water contains many dissolved substances or contaminants bacteria, viruses, heavy metals, nitrates and salts that can reach pollution levels due to inadequate treatment and disposal of human and livestock waste, industrial discharge, and overuse of limited water resources (Singh & Mosley, 2003). Indiscriminate waste disposal, poor agricultural practices, septic tanks, pit latrines and graves near boreholes all contribute to groundwater contamination, and these sources can account for the presence of nitrate in groundwater around the world.

Water scarcity is estimated to affect as much as one-third of the world's population in terms of consumption and migration patterns (Talafre & Knabe, 2009), and increasing population pressure and demand for irrigation has increased reliance on groundwater resources, creating challenges in providing adequate quantity and quality of water (WWDR, 2011). In Uganda, groundwater development is seen as more exposed to pollution than surface water (Xinghui et al., 2009), yet it remains a lower-cost option in the long run (Dhawan, 1991). Improved community water supply is linked to improved socio-economic conditions (Jan et al., 1993) through water security the relationship between availability, accessibility and use (Calow et al., 2011). Improved accessibility reduces the time and effort required to collect water, reducing workload, particularly for women, and increasing water available for productive activities such as small-scale gardening (Cairncross, 1987).

Identifying the factors that affect domestic water quality and consumption is important for managing available water resources (Keshavarzi et al., 2006). This research sought to identify factors affecting groundwater nitrate content in and around Nagongera town council.

1.2 Problem statement

Increased disposal of organic matter, which decomposes into nitrates, and increased use of fertilizer around the town council, some of which leaches into groundwater, raises the risk of groundwater pollution. In addition, most residents use pit latrines, which are a recognized source of groundwater pollution.

Elevated nitrate concentrations have serious impacts on human health; for instance, nitrate causes **methaemoglobinemia** in infants, which is a principal health concern for regulators globally. Nitrate is also implicated in cancer risk, since ingested nitrate is converted to nitrite, which reacts with natural and synthetic organic compounds in the stomach to form N-nitroso compounds, many of which are carcinogenic (IARC, 1978). It is against this background that this study sought to determine the level of nitrate content in and around Nagongera town council.

1.3 Objectives

1.3.1 Main/General objective

The main objective of the study was to determine the nitrate content of groundwater in and around Nagongera town council.

1.3.2 Specific objectives

The specific objectives of this study were to:

i. Determine the nitrate content in groundwater within Nagongera town council.

ii. Determine the nitrate content in groundwater approximately 10 kilometers outside Nagongera town council.

iii. Estimate the number of pit latrines located close to the boreholes sampled in and around Nagongera town council.

1.4 Research questions

i. What was the nitrate content in groundwater within Nagongera town council?

ii. What was the nitrate content in groundwater approximately 10 kilometers outside Nagongera town council?

iii. How many pit latrines were located close to the boreholes sampled in and around Nagongera town council?

1.5 Significance of the study

The quality of the water we consume is a critical determinant of quality of life. Access to clean water is an issue of global magnitude global water consumption continues to rise while water resources continue to dwindle due to poor environmental management (UNEP, 2000), and more than twenty-five thousand people die daily worldwide as a result of water-related diseases.

Because groundwater is the most reliable source of domestic water in and around Nagongera town council, and because high nitrate concentrations pose a documented health risk (EPA, 2008), it is important that the nitrate content of local groundwater points be determined. The findings of this research are intended to guide government agencies, researchers and development organizations such as **NGOs** in developing strategies, policies and infrastructure to provide safe and accessible water resources to the community.

1.6 Scope of the study

The study focused on the nitrate content of groundwater in and around Nagongera town council, Tororo District. Sample analysis was carried out at the Busitema University laboratory using the UV-VIS spectrophotometry method. The study was limited to the determination of nitrate content of groundwater and was conducted over two months, from March to May.

CHAPTER TWO LITERATURE REVIEW

2.1 Groundwater occurrence

Groundwater may be found in almost all types of geological formations, though its distribution in terms of quality and quantity varies from place to place (Fetter, 1994). Freeze and Cherry (1979) noted at least three factors that influence groundwater occurrence: the hydraulic properties of geological formations, the geological framework, and climate.

2.2 Sources of nitrate in groundwater

Nitrogen is essential to all living organisms as a component of protein and is the plant nutrient most limiting to crop production. People have long added nitrogen to soils through animal manure, human waste, legumes and fertilizers; nitrogen fertilizers are more commonly applied in ammonium form, which soil bacteria rapidly convert to nitrate.

Nitrate is highly soluble and moves readily with water through the soil profile, unlike ammonium, which is more tightly bound to soil exchange sites. Where nitrogen inputs exceed plant uptake particularly under irrigated agriculture with high fertilizer application the potential for nitrate leaching to groundwater is greatest. Because nitrate leaching is a natural process that predates human agriculture, it cannot realistically be eliminated entirely, though it can be managed (Lamond et al., 1999).

Although nitrate occurs naturally in groundwater, elevated levels are typically attributed to human activity, including improper well construction or siting, overuse of chemical fertilizer, and improper disposal of human or animal waste. Point sources such as septic and sewage systems (which remove only about half of the nitrogen in wastewater) and non-point sources such as unused fertilizer nitrogen are both significant contributors of nitrate to groundwater.

2.3 Health concern for nitrate

Nitrate contamination of groundwater is an often-overlooked health concern with both immediate and long-term effects. In the digestive tract, nitrate-reducing bacteria convert nitrate to nitrite, which is absorbed into the blood and oxidizes iron in haemoglobin, forming **methaemoglobin**, which cannot carry oxygen. The resulting reduced oxygen supply produces an acute condition **methaemoglobinemia**, or “blue baby syndrome” that develops rapidly and includes shortness of breath, blueness around the eyes and mouth, vomiting and diarrhea, and is of particular concern for infants and pregnant women (Kross, 2002).

Infants are especially susceptible because nitrate-reducing bacteria are abundant in their digestive systems before roughly six months of age, after which increasing stomach acidity suppresses these bacteria and reduces the risk. Similarly, ruminant animals (cattle, sheep, goats) and horses retain digestive conditions that favor nitrate-reducing bacteria into adulthood, making them more susceptible than humans to nitrate poisoning throughout life.

Healthy adults can tolerate nitrate intake at or somewhat above the maximum contaminant level (MCL) of 10 mg/L nitrate-nitrogen with little short-term effect, though long-term exposure at more than twice the MCL can produce low-level methaemoglobinemia. Other health effects under continued study include disruption of thyroid function (an inverse relationship has been observed between thyroid volume and serum TSH levels; Johannes et al., 1994) and developmental effects in children and animals.

2.4 Methods of removing nitrate from water

Nitrate contamination can be treated using technologies such as ion exchange, denitrification, and reverse osmosis, or through anaerobic reduction in the subsurface, which can limit nitrate contamination of groundwater (Kapoor & Viraraghavan, 1997).

CHAPTER THREE MATERIALS AND METHODS

3.1 Study site

The study was conducted in Nagongera town council, which covers approximately 26.5 square kilometers west of Tororo (West Budama), located at latitude 0°45′41″ N and longitude 34°01′34″ E in Tororo District, Eastern Uganda.

Nagongera town council experiences a bimodal climate with dry and wet seasons and receives an average annual rainfall of about 1,573 mm, with a dry season from November to early March and peak monthly rainfall typically between May and August. The main economic activity is agriculture, with food crops including millet, cassava, potatoes, beans and simsim, and cash crops including cotton and sorghum; cabbage is the main vegetable grown.

3.2 Apparatus, materials and reagents

The apparatus, materials and reagents used in this study were: a UV-VIS spectrophotometer, cuvettes, a hot plate, volumetric pipettes (2.5 ml and 10 ml), a calibrated pipette, a fume hood, an analytical balance, volumetric flasks, a weighing dish, a funnel, beakers, distilled water, measuring cylinders, hydrogen peroxide, hydrochloric acid, a refrigerator, a conical flask, nitrate reagent sachets, anhydrous potassium nitrate, a desiccator, chloroform, 500 ml water bottles, masking tape, a stirring rod and filter paper.

3.3 Sample collection

Ten water samples were collected in total: five from boreholes within Nagongera town council, and five from boreholes approximately 10 kilometers outside the town council, along the Nagongera–Paya–Kisoko route toward Tororo. Boreholes were selected at random within each zone.

GPS coordinates were not recorded at the time of sample collection. This omission was identified after the fact as a limitation of the original fieldwork, and since a return visit to the sampling sites was not possible, exact borehole-level coordinates cannot be reported. In place of exact readings, Table 3 (Section 4.4) reports approximate coordinates for each sampling site based on the named village, trading centre, or landmark recorded at the time of collection. These are estimates of the general locality only, not GPS fixes taken at the borehole itself, and this constraint is discussed further in Section 4.5 (Limitations of the Study).

Water samples were collected in 500 ml mineral water bottles, which were first rinsed with borehole water before filling, then transported to the Busitema University laboratory for analysis. Bottles were labeled to distinguish samples collected within the town council from those collected outside it. Samples were acidified with 1 M HCl to prevent interference from potassium hydroxide or carbonate concentrations up to 1,000 mg $CaCO_3$/L, and 1 M hydrogen peroxide was added to each sample to suppress interference from oxidizing and reducing agents. Samples were stored at

4°C and analyzed for nitrate content within a short period using the UV-VIS spectrophotometric method.

3.4 Standard preparation

A 1,000-ppm nitrate stock standard was prepared using potassium nitrate that had been dried in an oven for 24 hours at 105°C and stored in a desiccator until cool. 3.6107 g of potassium nitrate (KNO_3) was weighed and washed into a 500 ml flask with distilled water, then quantitatively transferred to a 1,000 ml volumetric flask and diluted to the mark with distilled water to give the 1,000-ppm stock standard. 10 ml of chloroform was added to suppress interference from other agents, and the solution was stoppered, shaken and labeled.

10 ml of the 1,000-ppm stock was pipetted into a 500 ml volumetric flask and diluted to the mark with distilled water, giving a 100-ppm intermediate standard, which was again stoppered, shaken and labeled. 10 ml of this 100-ppm standard was then pipetted into a 100 ml volumetric flask and diluted to the mark, giving a 10-ppm working standard.

Five working standards spanning the 0.1–0.5 ppm range used in Table 1 were then prepared by serial dilution of the 10-ppm working standard, with each aliquot made up to a fixed final volume of 100 ml in a volumetric flask, consistent with the dilution formula $C_1V_1 = C_2V_2$:

- 1 ml of the 10-ppm standard diluted to 100 ml to obtain 0.1 ppm
- 2 ml of the 10-ppm standard diluted to 100 ml to obtain 0.2 ppm
- 3 ml of the 10-ppm standard diluted to 100 ml to obtain 0.3 ppm
- 4 ml of the 10-ppm standard diluted to 100 ml to obtain 0.4 ppm
- 5 ml of the 10-ppm standard diluted to 100 ml to obtain 0.5 ppm

A calibration curve was then prepared from these five working standards (Table 1, Figure 1).

3.5 Sample preparation

Distilled water was used as a blank in these experiments. Water samples were collected in a container, and a fixed volume (10–25 ml) of each sample was placed into a cuvette. One sachet of nitrate reagent was added to the sample and the mixture was shaken vigorously for about two minutes until the powder dissolved completely. The mixture was left to stand for the specified reaction time (one to five minutes, depending on the reagent kit), during which a pink/red color developed, indicating the presence of nitrate. Samples were diluted as necessary, since the instrument reads absorbance most reliably at low concentrations, and nitrate levels were measured spectrophotometrically at a wavelength of 439 nm.

3.6 UV-VIS spectrophotometry methodology

Spectrophotometry is the quantitative measurement of the absorption or transmission properties of a material as a function of wavelength; this method is based on natural UV-VIS absorption and

associated chemical reactions (Gorog, 1995) and offers excellent precision. Its use in nitrate analysis has increased substantially in recent years. Aliquots of the samples prepared as described above were placed into disposable plastic cuvettes and analyzed using a UV-VIS spectrophotometer to determine nitrate content.

3.7 Ethical considerations

Informed consent was obtained from individuals at the locations where groundwater samples were collected. The purpose of the study, procedures and expected benefits were explained to local authorities by the researcher, and all waste materials, including bottles and used solutions, were disposed of properly.

CHAPTER FOUR RESULTS AND DISCUSSION

4.1 Calibration data

Table 1: Absorbance values of the five working standard solutions

Nitrate concentration (ppm)	Absorbance
0.1	0.042
0.2	0.064
0.3	0.092
0.4	0.125
0.5	0.145

Figure 1: Calibration curve of absorbance against nitrate concentration

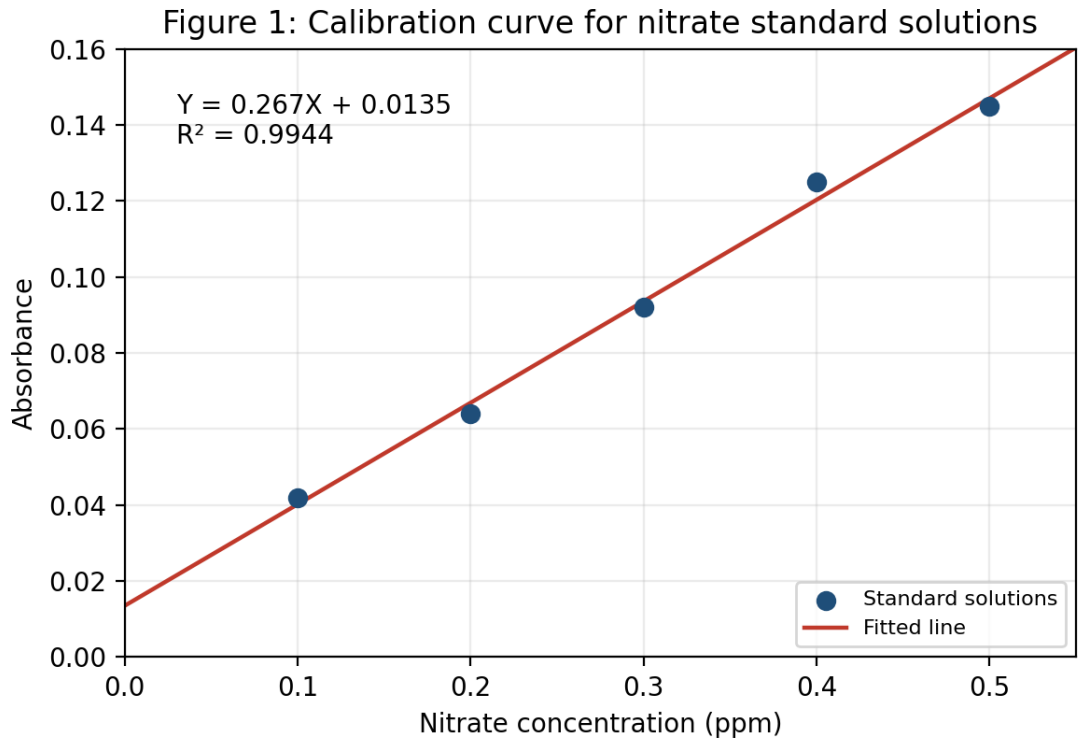

Figure 1: Calibration curve

A least-squares linear regression fitted to the data in Table 1 gives the calibration equation:

$Y = 0.267X + 0.0135$ ($R^2 = 0.9944$)

where Y is absorbance and X is nitrate concentration in ppm. This equation, rather than the originally reported $Y = 0.2863X + 0.0064$, is the one supported by the data in Table 1, and is the equation used to calculate the sample concentrations in Table 2 below.

4.2 Nitrate content of the water samples

Table 2: Calculated nitrate content of the ten water samples

Sample ID	Absorbance	Concentration (ppm)	Pit latrines nearby
1	0.183	0.6348	2
2	0.176	0.6086	0
3	0.178	0.6161	1
4	0.160	0.5487	0
5	0.183	0.6348	1
6	0.184	0.6386	1
7	0.176	0.6086	0
8	0.160	0.5487	0
9	0.183	0.6348	2
10	0.175	0.6049	1

Sample calculation (Sample 1): Concentration = $(0.183 - 0.0135) \div 0.267 = 0.6348$ ppm

Samples 1–5 represent boreholes within Nagongera town council; samples 6–10 represent boreholes approximately 10 km outside the town council. All ten samples returned nitrate concentrations between 0.5487 and 0.6386 ppm, well below both the Ugandan MCL (50 ppm) and the US EPA MCL (10 ppm) for drinking water (USEPA, 2007).

Samples 1, 5, 6 and 9 recorded the highest nitrate content, followed by samples 3 and 10, with samples 2, 4, 7 and 8 recording the lowest. Nitrate content did not track cleanly with the number of nearby pit latrines (compare, for example, samples 2 and 7, which had no nearby pit latrines but mid-range nitrate content, against sample 4, which also had no nearby pit latrines but the lowest nitrate content). This suggests that septic systems, animal waste, agricultural fertilizer use and naturally occurring geological nitrate sources are also contributing to the nitrate levels observed, consistent with the wider literature on nitrate sources in groundwater.

Although all values fall well below regulatory maximum limits, they fall within the 0.21–3.0 ppm band that Mueller and Helsel (1996) associate with combined human and anthropogenic influence, rather than the sub-0.2 ppm band typically associated with purely natural background levels. This indicates that borehole water in and around Nagongera town council already shows early signs of nitrate enrichment from human activity, even though it remains safe by regulatory standards at the time of sampling.

4.3 Limitation: calibration range and extrapolation

The absorbance values of the ten samples (0.160–0.184) exceed the absorbance of the highest calibration standard used in this study (0.145, at 0.5 ppm). This means the reported concentrations (0.5487–0.6386 ppm) were obtained by extending the calibration line beyond the range over which it was actually validated, rather than by interpolating within it. Because the fitted line closely followed the standards actually measured ($R^2 = 0.9944$), a modest extrapolation of this kind is unlikely to introduce large errors, but the values above 0.5 ppm should be treated as reasonable estimates rather than fully validated measurements.

For any future or repeat analysis, this should be corrected by preparing additional standards up to at least 0.7–0.8 ppm (or by diluting samples so their absorbance falls within the 0.1–0.5 ppm range and multiplying the result by the dilution factor), so that all sample concentrations fall within a validated calibration range.

4.4 Approximate sampling locations

As noted in Section 3.3, GPS coordinates were not recorded at the time of sample collection, and the sampling sites could not be revisited to obtain exact readings. Table 3 below therefore reports approximate coordinates for each sampling location, reconstructed from the named village, trading centre or landmark recorded during fieldwork, rather than coordinates measured at the borehole itself.

Table 3: Approximate sampling locations of the ten boreholes

Sample ID	Approximate location	Latitude (N)	Longitude (E)
1	Nagongera town council – central trading centre	0.7626	34.0140
2	Nagongera town council – Kakoli area	0.7650	34.0120
3	Nagongera town council – central ward	0.7600	34.0160
4	Nagongera town council – along Nagongera road	0.7660	34.0155
5	Nagongera town council – Namwaya area	0.7590	34.0110
6	Paya (~7.5 km north of Nagongera)	0.8322	34.0147
7	Along the Nagongera–Tororo road (~7 km east)	0.7500	34.0750
8	Kisoko trading centre (~11 km east)	0.7378	34.1095
9	Between Nagongera and Kisoko (~6 km east)	0.7450	34.0550
10	Along the Paya–Kisoko route (~9 km north-east)	0.7900	34.0700

4.5 Limitations of the study

This study has the following limitations, which should be considered when interpreting its findings:

1. **GPS coordinates**: exact borehole coordinates were not recorded during fieldwork and could not be obtained retroactively since a return visit to all ten sites was not possible. Table 3 reports approximate, village-level location estimates rather than measured coordinates.
2. **Calibration range**: sample absorbance exceeded the highest working standard used, requiring modest extrapolation of the calibration curve (Section 4.3).
3. **Sample size and frequency**: only ten boreholes were sampled once, over a two-month period. A larger number of boreholes sampled repeatedly across both dry and wet seasons would give a more representative picture of nitrate variation in and around Nagongera town council.
4. **Confounding sources of nitrate**: this study counted only nearby pit latrines as a potential nitrate source; septic tanks, animal waste, fertilizer use and geological background nitrate were not independently measured, limiting the ability to attribute nitrate levels to a single source.

CHAPTER FIVE CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

The ten borehole water samples analyzed in this study contained between 0.5487 and 0.6386 ppm nitrate, as determined by UV-VIS spectrophotometry using a corrected calibration equation ($Y = 0.267X + 0.0135$, $R^2 = 0.9944$). All values were well within the maximum contaminant levels set by Uganda (50 ppm) and the US EPA (10 ppm). Variation in nitrate concentration among samples did not track cleanly with the number of nearby pit latrines, indicating that other factors discussed in Chapters Two and Four also influence nitrate levels in groundwater in this area.

Although the nitrate concentrations recorded are below regulatory limits, they fall within a range (0.21–3.0 ppm) that is generally attributed to a mix of human and anthropogenic influence rather than a purely natural background level (Mueller & Helsel, 1996), indicating that groundwater in and around Nagongera town council is already showing early signs of nitrate enrichment from human activity and should continue to be monitored.

5.2 Recommendations

This study offers an initial picture of nitrate contamination in borehole water in and around Nagongera town council, but also raises questions worth addressing in follow-up work. A larger number of boreholes should be sampled, and sampling should be repeated at different times of year, to build a more complete picture of nitrate variation and confirm the conclusions drawn here.

Future studies should also record GPS coordinates for each borehole at the time of sampling, and should prepare calibration standards spanning a wider concentration range so that no sample absorbance falls outside the validated calibration curve.

Nitrogen isotope testing ($^{15}N/^{14}N$ ratios) is recommended as a further step, since it can help distinguish nitrate originating from human/urban sources (septic systems, animal waste), agricultural sources (fertilizer), and natural geological sources (Wolterink, 1979), which would allow more targeted remediation and prevention measures to be developed for the area.

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APPENDIX 1: RAW LABORATORY DATA

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