ASSESSMENT OF NITRATE LEVELS IN WATER AND SOILS FOR AGRICULTURE AND HUMAN UTILIZATION IN SINGIDA DISTRICT, TANZANIA

LEILA MOHAMEDY LWIZA

A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN SOIL SCIENCE AND LAND MANAGEMENT OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

2016

ABSTRACT

Population growth in urban areas has caused increase in demand of good quality water for domestic use. Due tohigh nitrate levels in water sources reported by District water authoritiesin Singida District, this study was carried to determine sources, levels and distribution of nitrates in water and soils for agriculture and human utilization. Firstly, a reconnaissance survey was carried to identify water sources with high, medium and low levels of nitrates and determine nitrate levels in surrounding soils. Surface water, underground water and surrounding surface soils samples were randomly collected and analysed for nitrate levels.Their results assisted in identifying areas with high, medium and low nitrate levels where detailed soil sampling and analyses for nitrate levels in soils was carried out.Analysis of soils and water resources revealed high levels of nitrates in water samples ranging from 105 to 476mgL^{-1}and25.2 to 114.8mgkg^{-1}in soils.The distribution of soil nitrates along transects indicated that higher levels were recorded at lower slopes whilelower levels were recorded in the upper slopes. The distribution of nitrate with soil depth was quite variable. In some areas the soil nitrate levels increased with increasing soil depth while in other areas nitrate levels decreased with increasing depths.The nitrate levels in water found to beabove the tolerable limits of 20 mgL^{-1} and 50 mgL^{-1}set by TBS (2005) and WHO (2007),respectively. Nitratelevels in soils are within the tolerable limits forcrop production. Due to observed high nitrate levels in water, more researchis required to generate sufficient data on the suitability of water for human consumption. The study on the dynamics ofnitrate in soils and water is recommended in orderto come up with strategies of reducing nitrate levels in water.

DECLARATION

I, Leila Mohamedy Lwiza, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work and that it has neither been submitted nor being currently submitted for a degree award in any other institution.

Leila Mohamedy Lwiza **Date**

(MSc. student)

The above declaration is confirmed by;

Prof. E. M. Marwa **Date**

(Supervisor)

Dr. A. K. Kaaya **Date**

(Supervisor)

COPYRIGHT

ACKNOWLEDGEMENTS

First and foremost Iam deeply indebted to the Almighty Allah, who provided me the courage, strength and ability to undertake this hard task. I also extend my sincere gratitude to my supervisors Prof. Ernest Marwa and Dr. Abel Kaaya of Sokoine University of Agriculture (SUA) for their kind support, invaluable comments and constructive criticisms during the whole period of my study. They were very cooperative and always available for assistance and support.

My studies would not have been completed without the financial support from the Commission of Science and Technology (COSTECH) who deeply committed to fund my MSc studies. For them Iam so grateful. I also extend my sincere thanks to the Ministry of Agriculture, fisheries and Livestock (my employer) for permitting me to attend my studies at Sokoine University of Agriculture. I am so indebted to my Deputy Zonal DirectorDr.C. Z. Mkangwa from the Agricultural Research Institute at Mlingano and my co-workers for not only providing me with the necessary tools I needed during my research work but also assisting me in one way or another when I was writing my dissertation

The assistance from theofficer-in-Charge,Mr. Bernad Chikarabani, of the Internal Water Drainage Basin in Singida and his co-workers are highly appreciated for their support, advice, sharing documents, mobilizing the farmers, key informants and communicating with local leaders and programme personnel to work closely with me and permission to utilize their office transport at times during data collection. Their cooperation put the foundation of this research work. My sincere appreciation goes to my beloved husband for his patience during my absence at home. With profound gratitude, I thank my beloved

parents Mr. and Mrs. Mohamedy Lwiza and my lovely sisters who encouraged me to study very hard. I am so grateful to you, may the AlmightyAllah bless you.

DEDICATION

This work is dedicated to my beloved parents, husband and my sisters for their patience and assistance during the entire period of my studies.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

PLATE

APPENDIX

LIST OF ABBREVIATIONS AND SYMBOLS

<	Less than
>	Greater than
AEC	Anion exchange capacity
ARI	Agricultural Research Institute
Ca	Calcium
CEC	Cation exchange capacity
Cl	Chloride
COSTECH	Commission Of Science and Technology
EMA	Environmental Management Act
K	Potassium
KCl	Potassium chloride
MDA	Minnesota Department of Agriculture
Mg	Magnesium
Mn	Manganese
N	Nitrogen
Na	Sodium
NH_4^+	Ammonium ion
NH_4OA_C	Ammonium acetate
NO_2^-	Nitrite
NO_3^-	Nitrate
NO_3-N	Nitrate-nitrogen
^{o}C	Degree Celsius
OC	Organic carbon

OM	Organic matter
pH	Negative logarithm of hydrogen ion activity (concentration)
SPSS	Statistical Package for Social Sciences
TBS	Tanzania Bureau of Standards
USEPA	United States Environmental Protection Agency
WHO	World Health Organization

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Low quality drinking water resources is threatening the health of people in cities of most of the developing countries including Tanzania. Purified water cannot be provided for everyone and still problems resulting from the spread of water associated diseases have not been solved (Lashgaripour *et al.,* 2001). Dissolved nitrogen in the form of nitrate(NO_3) is the most common contaminant in potable water while others include arsenic, fluoride, lead, pesticides, hydrocarbons and chlorinated hydrocarbons (Orebiyi *et al.,* 2010). Nitrogen, a plant nutrient supplied by organic and inorganic N- fertilizers is the main cause of high levels of nitrate in soils and water. Non-agricultural sources including discharge from wastewater treatment plants, runoff from fertilized lawns and cropland, failing septic systems, runoff from animal manure storage areas, and industrial discharges that contain corrosion inhibitors in residential areas also contribute to higher levels of nitrate in soils and water.

Nitrate is soluble in water and it can persist in ground water for decades and hence accumulate to higher levels. High levels of nitrate in drinking water is linked with gastric and oesophageal cancers (Gatseva and Argirova, 2008). Of greater potential concern is the tendency of nitrates to form N- nitroso compounds in the stomach by binding with organic precursors as amines derived from proteins. Certain N-nitroso compounds are known to be highly toxic, causing cancers, interfering with iodine uptake by the thyroid gland, stomach cancers and certain birth defects (Brady and Weil, 2008). World Health Organization (2007) reported fatal poisonings in infants less than six months by ingestion of well waters containing >50 mgL^{-1} of nitrates. Due to health problems associated to NO_3, the U.S.

Environmental Protection Agency (USEPA) has established a drinking-water standard of 45 mgL^{-1} ofNO_3(Spalding and Exner, 1993). In Tanzania, the recommended level of nitrate in potable water is 20 mgL^{-1} (TBS, 2005; EMA, 2007). Despite the WHO(2007) guidelines for drinking water quality, nitrate levels in groundwater have been increasing over recent decades in most countries (Razowska-Jaworek and Sadurski, 2005; Barbooti *et al.*, 2010; Jiban *et al.*, 2010).

1.2 Justification of the Study

Singida region is among the dry regions in central Tanzania with insufficient surface water for domestic uses. Drilled water wells are therefore used to supplement surface water for human and animal consumption. High levels of nitrate have been reported in the drilled water wells in Singida Districtwith levels ranging between 65.4 - 322 mgL^{-1} (Nkotagu, 1996; Kongola *et al.,* 1999).These levels are above the TBS (2005) and EMA (2007) recommended rate of 20 mgL^{-1}.The literature shows that, waters with levels above 50mgL^{-1}of nitrateare unfit not only for human but also for animal's consumption. The groundwater with high levels of nitrate varies from one place to another. What is not yet known is the actual cause and distribution of nitrate in groundwater and in the surrounding soils. Knowing the levels of NO_3 is necessary due to the health problems associated to it.Studies using animals indicate that high levels of nitrate in drinking water could cause pancreatic cancer (Ward *et al.,* 2005; Yang *et al.,* 2009). Furthermore, consumption of water with high nitrate levels indicated interact with amines and amides in the stomach and gut to form a variety of N-nitroso compounds (NOC) (nitrosation), which cause tumors(Ward, 2009).There is also a significant positive relationship between the levels of nitrate in drinking water and risk of death from bladder cancer (Chiu *et al.*, 2007). Thus, there was a need to assess nitrate levels in drinking water from different locations in

Singida District, and establish possible source(s) of nitrates. The generated information will be used as basis for creating public awareness on human safety and agricultural use.

1.3 Objectives

1.3.1 Overall objective

The overall objective of this study was to assess the levels of nitrate in soils and water for agriculture and human utilization in Singida District.

1.3.2 Specific objectives

i. To identify different human activities around the water sources that could possibly be contributing to the reported high levels of nitrates in soils and water.
ii. To carry out physical-chemicalcharacterization of the soils around the selected water sources.
iii. To determine concentration and distribution of nitrate in selected water sources and the surrounding soils.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Sources of Nitrates in Soils

There are several sources that may lead to the presence of nitrates in soils: some of them include nitrogenfixation by soil bacteria, decay of organic matter in the soil; application of commercial fertilizers and manures to fields, leakage from domestic septic systems, municipal sewage systems, manure storage and livestock housing facilities (Chiu *et al*., 2007; Fields, 2004).

2.1.1 Types of N fertilizers

Although nitrogen (N) fertilizers represent only one of several possible sources of nitrates in water, the tendency has been to blame commercial fertilizer use for high nitrate levels in water. Nitrogen loading in waterways through leaching of nitrate (NO_3^-) from agricultural fields contributes to eutrophication of rivers, lakes, and oceans (Burkholder, 1998; Mitsch *et al.,* 2001). In addition, pervasive groundwater NO_3^- contamination poses threats to human health and has been correlated to commercial fertilizer use in both developed and developing countries (Agrawal *et al.,* 1999; Mitsch *et al.,* 2001; Oenema *et al.,* 1998; Randall *et al.,* 1997).

The main nutrients applied routinely as fertilizers to agricultural soils are N, P and K (Hynes and Naidu, 1998). Nitrogen fertilizers unlike other fertilizers are heavily used worldwide. This is because in most of the agricultural systems, nutrients supply is below the minimum requirement of crops to reach maximum yield (Galvis-spinola *et al*., 1998). Important to note that, the nutrient and rate at which it is applied is based on the requirement of the crop to be grown at a particular time. All nutrients ought to be supplied in sufficient levels to meet optimal crop performance. If the soil cannot supply them, they are to be supplied through fertilization.

2.1.1.1 Inorganic N fertilizer sources

Nitrate (NO_3^-) is easily absorbed by plants at high rates unlike urea or ammonium. Nitrate is highly mobile in the soil and reaches the plant roots quickly. Therefore applying nitrogen as ammonium nitrate or calcium ammonium nitrate provides an instant nutrient supply. In addition, the negative charge of nitrate carries along with it positively charged nutrients such as magnesium, calcium and potassium.

CAN fertilizer is one of the forms of inorganic N fertilizers. It has a chemical formula of NH_4NO_3+ $CaMg(CO_3)_2$. The active ingredients of this fertilizer are the ammonium nitrate and very fine dolomite powder.The nitrogen in CAN is made up by the slow ammonium nitrogen and the fast nitrate nitrogen at equal ratio; therefore, it can be applied for both top dressing and basic fertilization for any kind of soil types and vegetation. Calcium and magnesium in the fertilizer compound improves the soil structure, and increases its fertility. It increases the absorption and utilization of other nutrients through improving the ion balance.

Ammonium nitrate is an odorless, colorless white crystal salt produced by the reaction of ammonia and nitric acid. It was the first solid nitrogen (N) fertilizer produced on a large scale (Vitosh *et al*., 1995). It is a common nitrogen source because it contains both nitrate and ammonium, and has a relatively high nutrient content. For some crops it is the most environmentally and economically viable N fertilizer. Ammonium nitrate is a popular fertilizer since it provides half of the N in nitrate form and half in ammonium form (Bremner and Shaw, 2005). The nitrate form moves readily with soil water to the roots where it is immediately available for plant uptake. It is less susceptible to volatilization or air losses when left on the soil. It is also valued by vegetable growers for its ability to provide an immediately available nitrate to plant (Bremner and Shaw, 2005).

Another fertilizer used as source of N is urea. It has a chemical formula of $CO\text{-}(NH_2)_2$ with an active ingredients of amide nitrogen. The cabarmide nitrogen in urea has a relatively long lasting effect. Urea-N, $((NH_2)_2CO)$ is hydrolyzed to NH_4^+ by the soil-borne enzyme urease.

When urea fertilizer is applied to the soil, it combines with water (hydrolysis) to form ammonium carbonate $[(NH_4)_2CO_3]$ through the catalytic action of urease. The enzyme urease is present in the soil resulting from the decomposition of soil organic matter by microorganisms.

Ammonium carbonate produced is unstable in the soil and it decomposes into gaseous ammonia (NH_3), carbon dioxide (CO_2) and water (H_2O). When incorporated to the soil NH_3 is converted to ammonium (NH_4^+) with hydrogen ion (H^+) coming from soil solution or from soil particles.

The urease reaction according to Jones *et al.,* (2012) may be summarized as:

$$(NH_2)_2CO + H_2O + H^+ + \text{urease} \Longrightarrow 2NH_4^+ \quad + \quad HCO_3^-$$

The ammonium ion (NH_4^+) reacts with the soil cation exchange complex and is immobilized. This means that NH-N does not move freely in soil solution (James and Topper, 1993). Ammonium-N (NH_4^+) is transformed to nitrate-N (NO_3^-) by soil bacteria in a process referred to as nitrification (James and Topper, 1993). The overall process may be illustrated by the reaction:

$$2NH_4^+ + 4O_2 \Longrightarrow 2NO_3^- + 4H^+ + 2H_2O$$

Unlike ammonium, nitrate (NO_3^-) has a negative charge which causes it to be repelled by negatively charged soil particles. As a consequence, nitrate doesn't stick to the soil thus travels readily through the soil profile with water. When water moves below the plant root zone, nitrate nitrogen will move with it, a process called leaching (Jones *et al.,* 2012).

2.1.1.2 Organic N fertilizer sources

Manure

They contain both macro- and micro-nutrients needed for crop production in organic and inorganic forms. Inorganic nutrients are readily available to the growing crop, while the organic nutrients become available through gradual mineralization over time. Crops respond to application of inorganic nutrients in soil, whether they originate from manure or commercial fertilizer. The manure nutrients of primary interest for crop production are nitrogen (N) and phosphorus (P).Ammonium N (NH_4-N) is the predominant inorganic form of N in manure and it is immediately available to the crop following application. It may be expressed as either ammonium or ammonia on the manure analysis and it is the same form of N as is in ammoniumbased commercial fertilizers.Nitrate N (NO_3-N) is another inorganic form of N. Although soil can contain significant quantities of nitrate it is typically present in manure in very low or insignificant amounts.

Crop residues

The harvested crops contain some nutrients extracted fromthe soil. Large quantities of nutrients have been reported in harvested parts of the crops. For example in a research trial that was conducted at Lyamungu in Kilimanjaro, Tanzania, Vaje *et al*. (1999) found that maize stems contained an average of 46 kg N ha^{-1} at harvest.Vaje *et al.*(1999) also found that, little nitrogen was returned in soil for the following season when the grains of leguminous crops were harvested. Most of crop bound nitrogen is fixed nitrogen and it is usually removed from the field. The same concentration of nitrogen present in the stalks leaves and roots of grain legumes, such as soybeans and beans were found in non-legume crop residue. In fact, the residue from a corn crop contained more nitrogen than the residue from a bean crop because the corn crop has more residues (Vaje *et al.*, 1999).

2.2 Chemistry of Nitrate in Soils

The study on the understanding of nitrogen dynamics in soils by Lamb*et al.* (2014) revealed that nitrate is always present in the soil solution and moves with the soil water. Inhibiting the conversion of NH_4^+- N to NO_3^-- N can result in less N loss and hence more plant uptake. Although it is not possible to totally prevent the movement of some NO_3^--N from soils into water sources,sound management practices can keep NO_3^--N losses within acceptable limits. Over narrow geographical areas, the texture of soil affects soil N content, which is generally higher in soils with finer texture (de Ruijter *et al.*, 2007).

2.3 Nitrogen Transformations inSoils

Nitrogen which is present or added to the soil, is subject to several changes (transformations) that dictate the availability of N to plants and influence the potential movement of NO_3^--N to water sources. These changes include mineralization, nitrification, denitrification and volatilization (Lamb *et al.,* 2014)

2.3.1 Mineralization

Mineralizationis the process by which organic N is converted to plant-available inorganic forms, mostly ammonium (NH_4^+) and nitrate (NO_3^-) by soil microbes (Crohn, 2004). Since more than 95% of the total N in most surface soils is organically combined, thenmineralization of organic N is important for plant nutrition and soil fertility (Crohn, 2004). Plants absorb N mainly in two forms: nitrate and ammonium ions. Nitrate, however, is the most available and important source to plants (Robertson and Groffman, 2007). It is estimated that about 25% of the organic N in manure is mineralized and made available to the next crop. The remainder becomes available during subsequent years at significantly decreased rates(Crohn, 2004).

2.3.2 Nitrification

Nitrificationis the microbial oxidation of reduced forms of nitrogen to nitrate (Addiscott *et al.,* 2005). It is carried out by three microbial groups: (1) autotrophic ammonia oxidizers, (2) autotrophic nitrite oxidizers, and (3) heterotrophic nitrifies. Autotrophic ammonia and nitrite oxidizers are characterized by their ability to oxidize ammonia sequentially to nitrate under aerobic conditions, but these organisms possess a wider metabolic diversity. This has significant consequences for their ecology, for the occurrence and kinetics of nitrification, and for interactions with other organisms. The major sources of reduced forms of soil nitrogen are excretion and decomposition of organic nitrogen derived from animals and plants and application of ammonia-based fertilizers. Many microorganisms and plants require ammonium for growth, while others assimilate nitrate. For both groups, nitrification is important in regulating the supply or loss of nitrogen from the environment (Addiscott *et al.,* 2005). While ammonia has a tendency to bind to soil particles, its conversion to nitrate leads to significant losses of soil nitrogen through leaching and conversion to gaseous forms through denitrification (Robertson and Groffman, 2007). Nitrification also contributes to soil acidification, with consequent increase in mobilization of toxic metals, particularly in heavily fertilized and poorly buffered soils(Addiscott *et al.,* 2005).

2.3.3 Denitrification

Denitrification is the process by which bacteria convert NO_3^--N to gaseous forms of N such as nitrogen oxide, nitrous oxide, nitric oxide and dinitrogen gas that are lost to the atmosphere. Denitrifying bacteria specifically pseudomonas and Micrococcus denitrificant use NO_3^--N instead of oxygen in the metabolic processes (Lamb*et al.,* 2014). Denitrification takes place in waterlogged soil and with ample organic matter to provide energy for bacteria. For these reasons, denitrification is generally limited to topsoil. Denitrification can proceed rapidly when soils are warm and become saturated for 2 or 3 days.

2.3.4 Nitrogen volatilization

Although nitrogen is quite stable in the atmosphere, the form of nitrogen in the soil can change very easily. Nitrogen volatilization refers to the process that involves the loss of N through the conversion of ammonium (NH_4^+) to ammonia gas (NH_3) which is released to the atmosphere (Johnson*et al.,* 2005). The volatilization losses increase at higher soil pH(greater than 8), and when the soil is moist and warm (Killpack and Buchholz, 1993). Volatilization losses are higher for manures and urea fertilizers that are surface applied than those which are incorporated (by tillage or by rain) into the soil (Johnson*et al.,* 2005). Manure contains N in two primary forms: ammonium and organic N. If manure is incorporated within one day, 65% of the ammonium N is retained; when incorporated after 5 days the ammonium N will have been lost through volatilization (Johnson*et al.,* 2005). The organic N in manure is not lost through volatilization, but it takes time to mineralize and become available toplants (Robertson and Groffman, 2007).

2.4 Factors Affecting Transformations of Nitrogen in Soil

Several factors affect the transformation of nitrogen in soils. These include;Oxygen status, soil pH, temperature, amount of organic matter, microbial population and soil type(Dave *et al.,* 2013).

2.4.1 Influence of oxygen in nitrogen transformations

The oxygen (O_2) status of the water and sediment layers plays a key role in determining potential N-transformation pathways(Dave *et al.,* 2013). Nitrate (NO_3^-) is very soluble in water and is negatively charged therefore moves readily with soil water through the soil profile, where it can reach subsurface tile lines or groundwater. Where groundwater remains oxygenated, nitrate remains stable and can travel in the groundwater until it reaches surface waters. Similarly, nitrate can move downward into tile lines, which then direct the drained water to ditches and surface waters. When nitrate encounters low oxygen/anoxic conditions in soils it may be transformed to N gasses through a biochemical process called denitrification (Dave *et al.,* 2013). Therefore nitrate is sometimes lost to gaseous N before reaching groundwater or being distributed to streams. Typically a smaller fraction of nitrate reaches streams in storm water runoff over the land surface (Minnesota Department of Agriculture-MDA, 2011).

2.4.2 Influence of temperature in nitrogen transformations

Optimum temperature of 30°C to 40°C is sufficient for nitrogen transformation from ammonium to nitrates in soils. This is because most of the transformation processes involved are controlled by microorganisms of which the majority operates at that range (Reddy *et al.,* 1989).

2.4.3 Effects of soil pH in nitrogen transformation

Optimum pH for microbial transformation of nitrogen in soils ranges from 6.5-8.5(Reddy *et al.,* 1989). This is based on the fact majority of soil microorganisms operates at that pH range. Forexample, Micrococcus denitrificant which are responsible for the transformation of NO_3^--N to N gases are highly affected when the pH is below 6.5 and above 8.5.High pH ranging from 8.5-10 favours ammonium volatilization which tend to increase above that range (Reddy *et al.,* 1989). Nitrate is usually deficient in acid soils because low pH less than 5.5 lowers the rate of nitrification. Nitrification ceases at pH less than 4.5.

2.4.4 Influence of soil organic matter in nitrogen transformation

Soils organic matter has a very big contribution in as far as the transformation of nitrogen in soils is concerned. It is an important source of nitrates in soils. The accumulation of nitrates in soils is closely related to the amount of soil organic matter present in the soil (Brady and Weil, 2008). Moreover nitrification depends on microorganisms which proliferate in presence of organic matter.Residues with high C:N ratio slows down the release of $NO_3^-$from organic matter because microorganismsimmobilize all available NO_3^- -N from the soilfor their growth(Brady and Weil, 2008).This delays the decomposition of organic matter and the associated nitrification.

2.5 Mobility of Nitrates in Soils

Mobility of nutrients within the soil is closely related to the chemical properties of the soil such as cation exchange capacity (CEC), anion exchange capacity (AEC) as well asthe soil moisture. When there is sufficient moisture in the soil leaching occurs, and the percolating water carries dissolved nutrients which will subsequently lost from the soil profile. The nutrients which are easily leached are usually those nutrients that are less strongly held by soil particles(Brady and Weil, 2008).

2.6 Soil Properties Influencing Mobility of Nitrates in Soils

2.6.1 Cation exchange capacity

The cation exchange capacity (CEC) is a measure of the soil’s ability to retain cationic nutrients. It measures the quantities of sites on soil surfaces that can retain positively charged ions by electrostatic forces (Riffald *et al*., 1994). The cations that can retain positive charged ions include Ca^{2+}, Mg^{2+}, K^+, NH^+, Na^+, and Mn^{2+} (Mwinuka, 2001).These ions are easily exchangeable with other cations in the soil solution and thus readily available for plant uptake. Therefore, the exchangeable cation determines, to a large extent the chemical and physical properties of soils (Brady and Weil, 2008). According to Landon (1996), the higher the CEC the more the fertile and productive the soil is. Soil CEC can provide a good estimate of soil texture. A low CEC soil may indicate that, the soil has a sandy texture while a high CEC indicates the soil has high clay content and is likely fine textured. The soil texture determines the amount of water held by the soil and how fast it moves through the soil profile. Coarse-textured soils have lower water holding capacity and, therefore, greater potential to lose nitrate by leaching when compared with fine textured soils (Landon, 1996).Soil texture, organic matter, clay content and type and soil pH are the factors that affect CEC. Depending on types of clays in certain soils, fine textured soil tends to have higher CEC than coarse textured ones.

2.6.2 Anion exchange capacity

Anion Exchange Capacity**(AEC)** is the measure of the soil's ability to adsorb and exchange anions(Riffald *et al.*, 1994). It results from the protonation of hydroxyl groups on the edges of silicate clays and on the surfaces of metal oxide clays(Riffald *et al.*, 1994). AEC is dominant in soils dominated by seisquioxide. These ions include Cl^-, NO_3^-, HS^-, $SO_4^{2-,}$ HCO_3^-, and CO_3^- which are adsorbed by ion exchange. AEC is inversely related to pH. Due to the fact that AEC of most agricultural soils is small compared to their CEC, mineral anions such as nitrate are repelled by the negative charge on soil colloids. These ions remain mobile in the soil solution and thus susceptible to leaching (Mwinuka, 2001).

2.6.3Soil moisture

Nitrate leaching only occurs when water is passing through the soil, thus the extent of nitrate leaching is related to the amount of water percolation(Brady and Weil, 2008). Any water management practice that limits percolation can limit nitrate loss. Usuallynutrients which are easily leached are those nutrients which are less strongly held by soil particles(Brady and Weil, 2008). For instance, soil with low AEC will leach much more readily than soils with high CEC. This is based on the fact that anions such as nitrate are repelled by the negative charge on soil colloids (Mwinuka, 2001). These ions remain mobile in the soil solution thus susceptible to leaching.

2.7 Process Causing Nitrate Losses from the Soil

2.7.1Nitrate leaching

Nitrate leaching refers to downward movement of dissolved nitrates in the soil profile with percolating waters (Halvin *et al.,*2005). The phenomenon is more prevalent in areas with high rainfall than in arid areas. Percolation losses are influenced by the amount of rainfall and its distribution, runoff from the soil, evaporation, nature of the soil and vegetations (Brady and Weil, 2008). Generally, nutrients leach from soil solution after been displaced from the exchange sites by other nutrients. Nitrogen in the form of NO_3^- is highly mobile in soils and generally follows the flow of water (Benson *et al*., 1992). Leached nitrates may contribute to groundwater contamination in areas with intensive agriculture(Halvin *etal.,*2005). Nitrate contamination of groundwater is a concern, particularly if the groundwater is a source of drinking water (Vaje *et al*., 1999).Leaching of nitrates willcontinue downward and into groundwater depending onthe underlying soil or bedrock conditions as well as depth to groundwater (Killpack and Buchholz, 1993). If the depth to groundwater is shallow and the underlying soil is sandy, the potential for nitrates leaching is relatively high. However, if depth to groundwater is deep and the underlying soil is heavy clay, nitrates will not likely leach into the groundwater. In some cases where dense hardpans are present, nitrate leaching will not progress beyond the depth of the hardpan(Killpack and Buchholz, 1993).

2.7.2 Soil erosion

Nutrients are lost when the soil is eroded. The amount of erosion greatly affects the loss of NH_4^+ and P (Vaje *et al*., 1999). However,how much is lost depends on the extent of soil erosion. Accelerated soil erosion affects the soil both physically and chemically (Hajek *et al*., 1990).Runoff and erosion losses may include nitrate (NO_3^-),ammonium (NH_4^+), and organic nitrogen. The negatively charged NO_3^- ion remains in the soil water and is not held by soil particles. If water containing dissolved NO_3^- or NH_4^+ runs off the surface, these ions move with it (Provin *et al.,* 2001).The increase in nutrient levelsmay be observed in the site receiving the eroded soils (Vaje *et al*., 1999) like ponds where people use to collect drinking water, the case of Singida District.

2.8 Nitrates in Water

Continuous application of N fertilizers and buildup of soil organic matter results into a large mineral pool and thus, the higher the risks of nitrate contaminating groundwater due to high rate of leaching (Korsaeth and Eltum, 2000). Furthermore, crop cultivation practices have been found to influence the extent of nitrate leaching. Climatic factors influence the N content of soils through the effects of temperature and water flows on the growth of plants and activities of soil microorganisms. Higher temperature results in low nitrate contamination of groundwater possibly due to the increased evapotranspiration. Areas which receives high amount of rainfall results into low concentration of nitrate in underground water (Wick *etal*., 2012).

The study byWells *et al.* (1991) revealed that the concern about nitrate nitrogen (NO_3^--N) and its effect on water quality has greatly intensified in recent years. The public has become aware of the potential health consequences of consuming high-nitrate through drinking water. This concern has led the governments to initiate a much stronger regulatory system for domestic water supplies. In Tanzania, Tanzania Bureau of Standards (TBS) set athreshold contaminant level of20 mgL^{-1} in water used for human consumption to be of nitrates (TBS, 2005).

2.9Concentration andDistribution of Nitrates in Groundwater in Tanzania

2.9.1 Concentration of nitrate in groundwater in the internal drainage basin

The Internal Drainage Basin is described by rivers/streams draining into a group of inland water bodies (lakes) that are located around the north-central part of Tanzania. The Internal Drainage Basin runs southward from the border with Kenya to central Tanzania. Groundwater is the main source of drinking water, irrigation and industrial activities particularly in Singida, Manyara, Shinyanga, Dodoma and Arusharegions (Bowell *et al.,* 1997; Pittalis, 2010; Nkotagu,1996;Rwebugisa, 2008). Bowell *et al.* (1997) reported high nitrate concentration in drinking water reaching 180mgL^{-1} which positively correlated significantly with coliform counts of the groundwater samples collected from Manyara and Arusha regions. Such high nitrate concentration associated with positive correlation of coliform counts reflects contamination of groundwater to be originating from human and animal faecal matters.

The study by Nkotagu (1996) showed that nitrate concentrations in groundwater samples collected from Hombolo sub-basin in Dodoma District ranged from 0.01 to 449.1mgL^{-1} with a median of 52.8mgL^{-1}. About fifty percent of the samples had nitrate concentration higher than the maximum concentration of 50mgL^{-1}recommended for drinking water by

WHO (2007), while 76% of the samples had nitrate concentrations above background concentration of 10 mgL^{-1}. These results indicate that about 76% of the water samples were contaminated by nitrate resulting from humanactivities specifically onsite sanitation (particularly pit latrines) and animal manure since the area was occupied by pastoralists, and there was insignificant application of industrial fertilizers. The significant negative correlation between nitrate concentration and pH was observed owing to mineralization and nitrification of organic nitrogen from animal manure and/or human wastes in either the aquifer or unsaturated zone (Nkotagu, 1996). Rwebugisa (2008) reported nitrate concentration ranging from 0.0 to 150 mgL^{-1} and median of 20 mgL^{-1} in groundwater samples collected from Makutupora, Msalato and Dodoma Urban centre. It was reported that eighteen percent of the groundwater samples had nitrate concentration higher than the maximum concentration recommended for drinking water by WHO (2007), while 55% of the samples had nitrate concentrations above background concentration of 10 mgL^{-1}. It was also noted that the concentration of nitrate in protected areas (areas free from human invasive activities) of Makutupora was low compared to the other areas. The levels ranged from 0.9 to 32 mgL^{-1} below the maximum concentration recommended for drinking water by WHO (2007). Such low nitrate concentration in the groundwater samples collected from Makutupora boreholes was probably a result of prohibition of human activities around the area.

2.9.2Variation of nitrate concentration in water with depth

Variation of nitrate concentration with depth depends on the land use, climate, hydrogeology, biological composition and physicochemical properties of the area. Mtoni (2013) reported a decreasing trend of nitrate concentration in groundwater as the depth of the well increased. According to Mtoni (2013) the concentration of nitrate increased from below 10 m reaching a maximum depth between 15 and 20 m deep then decreased.

Furthermore, Kibona *et al*. (2011) reported a significant negative correlation between nitrate concentration and well depth. According to Kibona *et al.*(2011),the highest concentration of nitrate (32.5 mgL^{-1}) was reported in wells of less than 35 m deep and then decreased gradually to 1.4 mgL^{-1} at a depth of 65 m. The decrease in nitrate concentration with depth can be attributed to the anoxic condition which is common in deep wells. In anoxic condition, nitrate will be the electron acceptor of choice, hence easily reduced (Kibona *et al.,* 2011). With little or no oxygen, microorganisms use nitrate as an electron acceptor to oxidise organic carbon. In sodoing nitrate concentration is lowered or depleted (Kibona *et al.,* 2011).

2.10 Trends of Nitrate Concentrations in the Groundwater in Tanzania

The degree of nitrate contamination in groundwater is mainly a function of past and present land use particularly agriculture and settlement (Kashaigili and Majaliwa, 2010). Trends in nitrate concentration in the groundwater require long-term records of a particular aquifer.. For example, nitrate concentration in some unprotected boreholes in Makutupora,Dodoma increased from natural concentration of 0.1 to 10 mgL^{-1} in 1983 to above 100 mgL^{-1}in 2004 (Rwebugisa, 2008). Furthermore, the average concentration of nitrate in protected Makutupora well field has been gradually increased from an average of 0.85 mgL^{-1}in 1983 to an average of 31.87 mgL^{-1}in 2004. Similar trends were derived from few studies conducted in Dar es Salaam. The study conducted by Mato (2002) reported high values of nitrates concentration in groundwater up to 151 mgL^{-1}. About 5 years later, the study conducted in the same area by Mjemah (2007) reported a maximum level of nitratesof 421 mgL^{-1}in water. Furthermore, Mtoni *et al*. (2012) and Bakari *et al*. (2012) reported 435.4 and 445 mgL^{-1}nitrate levels in water respectively, in Dar es Salaam in 2010 to 2011. The trends from these studies indicate that the concentration of nitrate in groundwater is increasing with time. However, this observation cannot be conclusive because the reported values may not be of water samples from the same boreholes.

2.11 Effects of High Levels of Nitrate in Drinking Water

The highly soluble nitrate form of N is the major concern in terms of impacts of excess N on the environment and humans. Nitrate contamination is particularly harmful to infants and young children in causing methemoglobinemia, a reduction in the blood haemoglobin level (Spalding and Exner, 1993).Therefore because of the observed health hazard, a national standard in Tanzania was established to declare maximum nitrate contaminant levelsof 20mgL^{-1}in water(TBS, 2005; EMA, 2007).

2.12 Nitrate Poisoning in Livestock

Nitrate poisoning is a condition which may affect ruminants consuming certain forages or water that contain an excessive amount of nitrate. Nitrate itself is not particularly toxic to animals. Most forage contains some amount of nitrates. When feeds containing nitrates are consumed by ruminants, nitrates are changed to ammonia in the rumen, which in turn is converted by bacteria in the rumen into microbial protein (Undersander *et al.,* 1999). Nitrite(NO_2) is one of the intermediate products in the breakdown of nitrates within the rumen and is the actual cause of nitrate poisoning. If nitrate intake is faster than its conversion to ammonia, nitrites will begin to accumulate in the rumen. The accumulated nitrites are absorbed rapidly into the blood systems where it oxidizes haemoglobin to methemoglobin. Red blood cell containing methemoglobin cannot transport oxygen thus the animal will eventually die from asphyxiation.However, the occurrence of nitrate poisoning is difficult to predict because nitrate levels can change rapidly in plants and the toxicity of nitrate varies greatly among livestock due to age, health status, and diets.

According to Undersander *et al*. (1999), the steps of conversion of nitrate into protein are as follows:

Nitrate (NO_3^-)——› Nitrite (NO_2^-)——› Ammonia (NH_3) ——› Amino Acid ——› Protein

2.13The Effects of High Levels of Soil Nitrate on Plant Growth and Development

The increase in nitrate, like the increase in any salt will increase the osmotic concentration of the soil solution (Brady and Weil, 2008).The roots of the plant then have to take up minerals from a more and more concentrated solution. If the solution outside gets too concentrated, there will come a point where the plant is not able to take up any water against the concentration gradient and the plant will start to wilt(Brady and Weil, 2008).

Being one of the sources of N to plants, nitrate is essential for carbohydrate use within plants. It stimulates root growth and development as well as the uptake of other nutrients (Brady and Weil, 2008). It increases the plumpness of cereal grains, the protein contents of both seeds and foliage as well as the succulence of lettuce and radishes.

Excess nitrate in plants degrades not only crop quality, which may results in undesirable color and flavor of fruits but also lowers sugar and vitamin levels of certain vegetation and root crops(Brady and Weil, 2008). Growth inhibiting environmental conditions such as drought, dark cloudy days or cool temperatures can exacerbate the accumulation of nitrates in tissues because plant conversion into protein is slowed. The leaching of excess nitrates from the soil can lead to environmental degradation of downstream water basins(Brady and Weil, 2008).

Based on the studied literatures, nitrates levels in water are persistently increasing with time.However,very little was known as to why nitrate levels were persistently increasing over time. In filling this gap the study was done to assess nitrate levels in water and soils for agriculture and human utilization in Singida District.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the Study Area

3.1.1 Location of study area

The study was conducted in Singida Urban districtwhich lies in the Central plateau of Tanzania between Latitudes4°44′52″Sto4°52′59″S, and Longitudes34°37′23″Eto 34°48′13″E(Fig. 1). The District covers an area of 754 square km and has the population of about 150,379 people (National Bureau of Statistics, 2012). Major economic activities of the District's residents are livestock keeping, agriculture, horticulture, trading, and employment in public and small scale industries especially in agro-business and furniture makings.

3.1.2 Physiography and climate

Singida Districtis characterized by isolated hills of granite and three inland lakes. The climate in the area is humid with two distinct seasons; a rainy season which start from November to May and a dry season from June to October. The mean annual rainfall ranges between 600 to 800 mm per year and the average temperature ranges from 15to 32ºC (Swai *et al.,* 2012). In addition, the District experiences flash floods during rainyseasons with high evaporation rate and severe soil erosions which are caused by surface runoff, strong winds and relative low humidity (Swai *et al.,* 2012).

3.1.3 Geology and soils

Geologically most of the areas in Singida Urban district are covered by granite rocks rich in biotite (JICA, 2008).

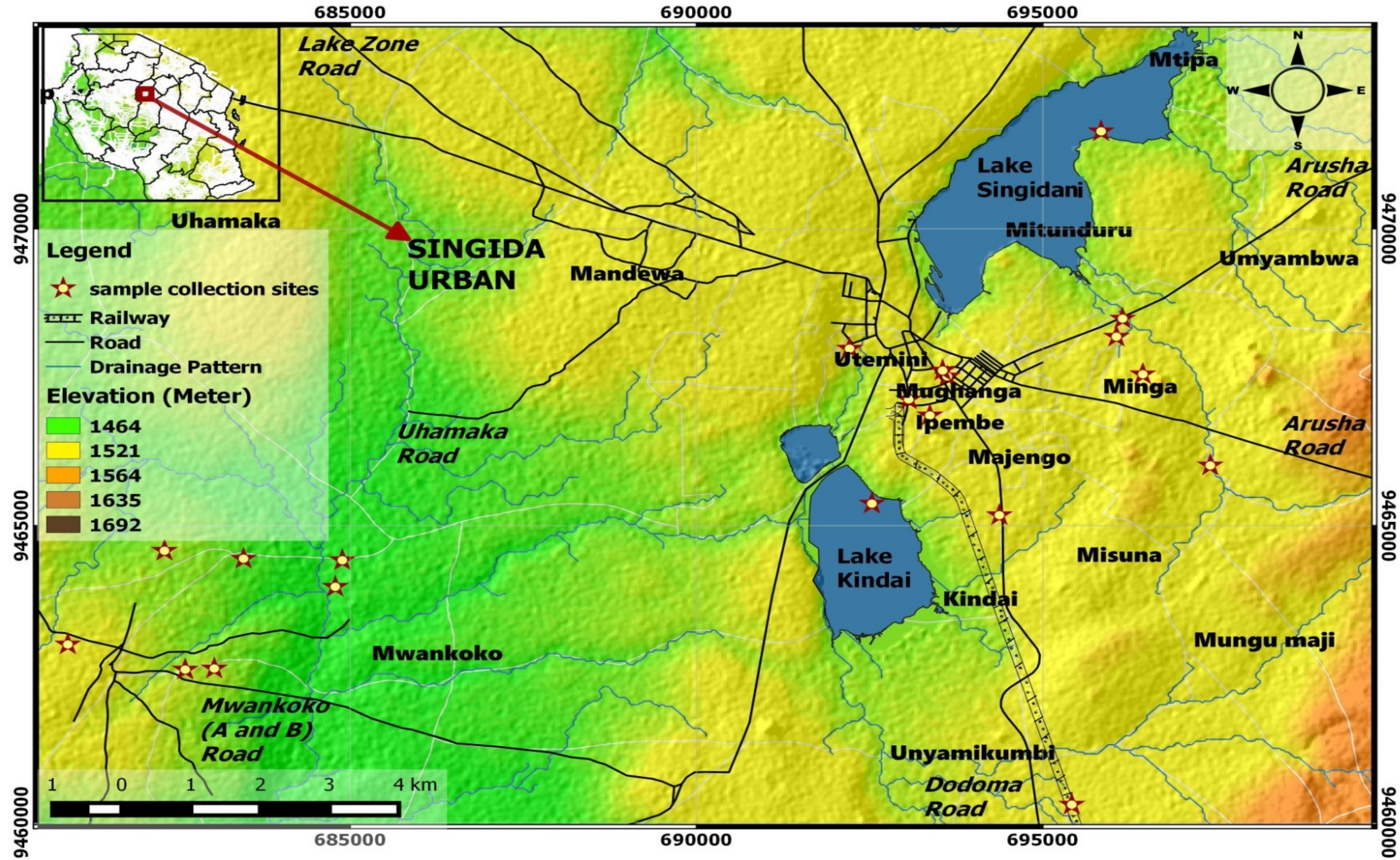

Figure 1: Location of the study area

However, there are some patches of gneissic biotite granite which has undergone metamorphism in the northern and southern part of the District. On the eastern part of the gneissic biotite granite, there are some patches of biotite muscovite granite. The biotite granite is surrounded by granodiorites. Furthermore, on the south-west of Mwangaa and Manyongo villages, there are hornblende syenites (Petro *et al.,* 2014).

There are two basic geological structures which might have an influence on the transfer of nitrate within the District. These include the Singida fault on the northern part and the Turu fault on the southern part. Singida fault trends from North North East (NNE) to South South West(SSW), while the Turu fault trends from North East (NE) to South West (SW). In between these two faults, there are several minor faults crosscutting the major faults (Petro *et al.,* 2014). These faults are very permeable hence carries water which may have high levels of nitrates from higher concentrated areas to lower concentrated areas.

Within the District there are three inland lakes namely; Kindai, Singidani and Mikuyu,all of which have closed drainage systems. There arealso kenke swamp and several seasonal rivers which feeds the inland lakes(Petro *et al.,*2014). The soils of Singida Districtare deep to moderately deep ranging from sand to loamy sandy resulting from weathering of granitic rocks. The fertility status as well as the organic matter contents of these soils is generally low. In some areas salt contents is very high and tend to precipitate on the surface especially during dry seasons(JICA, 2008).

3.1.4 Vegetation and land use

Much of Singida Urban district is covered by savannah, scattered trees and short grasses, though in some areas there are thick miombo woodlands(JICA, 2008).The dominant land use in this area is mainly livestock keeping and cultivation. The economy of more than 75% of the population depends upon small scale agricultural activities. The main food and cash crops are rainfed crops such as maize(*Zea mays*), finger millet (*Eleusine coracana*), sorghum(*Sorghum bicolor*) and sunflower(*Helianthus annuus*).Productions of salt(Plate1), soda ash and fishing are other economic activities taking place in the study area. Fishing is carried out in swamps and lakes mainly at Singidani and Kindai.

Plate 1: Salt making process at Singidani Lake, Singida Urban District, Tanzania

3.2 Pre-field Activities

Before actual field work was conducted, geological and topographic maps and other reports from the internal drainage basin office were consulted. These reports helped to obtain background information and identification of sampling sites before the actual field work.Topographic maps were used to identify location of sampling sites along the transectswhile geological maps were used to identify geological features mainly rock features as seen on the earth's surface.

3.3 Field Work Activities

3.3.1 Water sampling

Underground and surface water samples were collected randomly within Singida District in order to determine the levels of nitrates, hence to evaluate their safety for domestic consumption. Three surface water samples each fromtwo lakes namely Singidani and Kindaiwere collected; at the edge, middle andbetween the edge and middle of the lake.The water samples were then mixed together to obtain a representative composite water sample from each lake.

Underground water samples (boreholes)from different sources were collected at random. A representative sample of water from each tap selected was collected in such a way that water were left to run for two minutes before being collected to a specified 0.25L bottle. The samples collected were stored in a cool box in order to avoid losses of nitrates through denitrification.

3.3.2 Soil sampling and preparation

Free reconnaissance survey was carried out using transect walks. Triplicateauger samples at a depth of 0-30cm were taken in order to identify areas with high, medium and low levels of nitrate in soils. The samples were then mixed thoroughly to make the representative composite soil samples. Composite soil samples were kept in plastic bags and stored in a cool box in order to avoid losses of nitrates through denitrification.

Based on the information obtained from the reconnaissance survey a detailed soil sampling was carried out. A total of 35 soil samples at a depth of 0-30cm, 30-60cm and 60-100cm in the selected sites were collected by using an auger at different slope positions (lower slope, mid slope and upper slope). This sampling technique was employed in order to determine the distribution of nitrates along the profile and laterally along the selected transect as influenced by water movement. The samples were then kept in plastic bags and stored in a cool box ready for analysis.

Soil samples for determination of other soil parameters including particle size distribution (soil texture), pH, CEC, and organic carbon and electrical conductivity were air dried, grounded and sieved through a 2mm sieve.

3.4 Laboratory Analyses

3.4.1 Nitrates in soils and water

Analysis of nitrate levels in soils and water samples was carried out in the Soil Science Laboratory at Sokoine University of Agriculture. Steam distillation method as described by Bremner and Keeney (1966) was used to determine nitrate levels in soils and water. Samples with high, medium and low levels of nitrates were identified and ranked according to WHO (2007) and TBS (2005) specifications.

Analysis of other soil parameters was carried out at the Soils Research Laboratory at ARI, Mlingano, Tanga. Those parameters were selected because they have influence on the mobility of nitrates in soils.

3.4.2 Soil texture

Particle size analysis(soil texture) in the soil samples from each site was carried out by the hydrometer method after dispersion with sodium hexa-metaphosphate (Gee and Bauder, 1986).

3.4.3 Soil pH, organic carbon and total nitrogen

Soil pH was measured potentiometrically in 1:2.5 soils: water ratio and soils: KCl ratio as described by Moberg (2000). The pH was determined using a pH meter (McLean, 1982; Moberg, 2000). Organic carbon was determined by wet digestion method (Nelson and Sommer, 1982)and OC was converted to organic matter by multiplying by a factor of 1.724 as described by Duursma and Dawson (1981). Total N was determined by micro-Kjeldahl digestion followed by distillation as described by Bremner and Mulvaney (1982). Furthermore, soil moisture was also determined by oven drying the soil at 105^{o} C to a constant weight.

3.4.5 Cation exchange capacity

Cation exchange capacity(CEC) of the soil was determined by saturating the soils with neutral 1*M* NH_4OAc (ammonium acetate) and the adsorbed NH_4^+ were displaced by using 1MKCl and then determined by Kjeldahl distillation method for estimation of CEC of the soil (Chapman, 1965).

3.5 Human Activities that May Influence Levels of Nitrates in Soils and Water

Alongsidewith soiland water sampling activities, a questionnaire with a list of open and close ended questions was administered to the people in the study area. The questionnaire aimed to determine the contribution of human activities on the levels of nitrate in water and soils within the District. The questions included information on use of organic and inorganic fertilizers, economic activities especially agriculture and livestock keeping as described in Appendix1. Furthermore, information concerning domestic and industrial waste disposals as well as mining activities involving the use of explosives and chemicals within the area were assessed.

3.6 Data Analysis

Information gathered from the administered questionnaire survey(questionnaires) was coded and data entered in SPSS version 16 for the assessment of the type of fertilizers used, frequency of application, the rate of application as well as the time of application. On the other, hand data on soil parameters was entered in MS-Excel for evaluation of which histograms and tables were generated.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Influenceof Various Human Activitiesto Increased Levels of Nitrates in Water andSoils

4.1.1 Economic activities around water sources

Results on social economic activities of the people around water sources are summarized in Table 1.

Table 1: Economic activities of residents around water source (n=20)

Activity engaging in	Frequency	Percent
Crop cultivation only	5	25
Crop cultivation and livestock keeping	15	75
Total	**20**	**100**

The results based on social economic activitiesof people surrounding the water sources revealed that 75% of total population being interviewed is engaged in small scale farming and livestock keeping while 25% are only engaged in small scale farming. There was no evidence of mining activities taking place within the study area.

4.1.2 Crops grown around the water sources

Majority of farmers in the study area use hand hoes for land preparation for crop growing. Planting of crops is done during rainy seasons along the contours. After harvesting most farmers leave crop residuals in their farmsto decompose.The decomposition of plant residuals is through the microbial mediated progressive breakdown of organic materials into carbon and other nutrients including N. The incorporation of these organic materialsinto the soil modifies the physical properties of soil and improves the biochemical properties including soil microbial activities. The major crops grown around the water sources are presented in Table 2.

Table 2: Major crops grown by respondents around the water sources (n=20)

Crop grown	Frequency	Percent
Maize	4	20
Sunflower	1	5
Beans, maize, finger millet and sunflower	1	5
Maize, finger millet and sunflower	11	55
Maize and sunflower	1	5
Maize and finger millet	2	10
Total	**20**	**100**

The findings of crops grown revealed that 55% of the respondents grow sunflower, maize and finger millet. Twenty percent of the respondents grow maize only while 5% grow beans, maize, finger millet and sunflower. Results (Table 2) clearly indicated that maize, finger millet and sunflower are the dominant crops withinthe study area. According to Sharma *et al*. (2007) sunflower has a high C:N ratio which upon decomposition increases the availability of N in soil. The decomposition of these crop residuals (sunflower, maize and finger millet) might have a big contribution towards the increased nitrate levels in surface soils.

4.1.3 Types, rates and time of fertilizer application in farms

Application of both industrial and animal manureimproves not only cropquality but also physical and chemical properties of the soil. Furthermore fertilizers application may influence levels of nitrates in soils especially the long term application of N fertilizers like urea and ammonium sulphate(Galvis-spinola *et al*., 1998). The findings regarding fertilizer application and their rates per unit area are summarized in Table 3.

Table 3: Respondents response on application of fertilizers by type, rate and time in farms around the water sources

Variables	Categories	Frequency	Percent
Fertilizer application in crops	Yes	18	90
	No	2	10
	Total	**20**	**100**
Type of fertilizer applied	Organic	15	83.3
	Inorganic	1	5.6
	Both organic and inorganic	2	11.1
	Total	**18**	**100**
Rate of fertilizer application	50kg of urea, a tonne of manure per hectare	3	15
	2000kg per hectare-manure	1	5
	50 kg of urea, 500kg manure	1	5
	50 kg per hectare	1	5
	4000kg per hectare	9	45
	500 kg per hectare	2	10
	1000 kg per hectare	3	15
	Total	**20**	**100**
Frequency	Once	15	83.3
	Twice	3	16.7
	Total	18	100
Time of applying fertilizer	Before	14	77.8
	After	1	5.6
	Before and after planting	3	16.7
	Total	**18**	**100**

Results (Table 3) revealed that 90% of the respondents apply fertilizers in their farms while only 10% does not. Furthermore the results revealed that 83% of those who apply fertilizers apply animal manures only specifically cow dung manure while 11% apply both animal manure and industrial fertilizer (Urea). The results also indicated that more than 75% of the respondents apply more than four thousand kilogram per hectare of fertilizers (manure) in their farms. The time of fertilizer application per unit area was also evaluated and that, 84% of the respondents applies fertilizers once before planting seasons while 16% of them applies before and after planting.

Therefore based on the results from the questioners it is clear that, human activities particularly agriculture, application of natural fertilizers (manure) and improper disposal of wastes might have been contributed to the observed high levels of nitrates. Concentration of animals (livestock) in a small area as revealed during the study might have also contributed to higher levels of nitrates in soils as well as water. Application of fertilizers specifically manure has a big contribution in as far as the increasing contents of nitrates is concerned within the study area. Despite the fact nitrate content in manure is present in a very small amount, continuous application of large quantities of manure as observed in the study area will subsequently increase their concentration in surface soils and therefore underground water in case of leaching. The observed results have been supported by the study conducted by Rwebusiga (2008) in Makutupora, Dodoma within the same drainage basin. According to Rwebusiga (2008), the increase in nitrate concentration in water sources is highly influenced by human activities particularly application of fertilizers, onsite sanitation as well as improper disposal of domestic industrial wastes.

Local industries that are close to water sources that might have contributed to high levels of nitrate within the study area are sunflower processing industries. The only waste product that is released from these industries is the sunflower husks. Concerning the disposal of domestic wastes, the survey revealed that most of the respondents within the study area dispose their domestic wastes in their farms and very few dispose their wastes in the dug waste pits. These wastes can be of organic origin including food wastes, fruits, vegetable peels and flower trimmings. These wastes are biodegradable (easily broken down by other organisms over time and turned to manure). Others can be of recyclable type (changing the useless form of waste into a useful form). These wastes include aluminium products like tomato cans, milk cans or soda cans. Other domestic wastes are hazardous. These wastes are harmful not only to human health and animals but also the environment as whole. They include wastes like used pesticides, batteries, mercury containing equipment.

4.2 Soils

4.2.1 Soil physical properties

The data of particle size analysis and textural classes of the studied soilsin the study area are presented in Table 4. The particle size distribution showed that the textures of top soils varied from sandy clay loam, loamy sandy, sandy loam to sandy clay. The sub-soils textures ranged from sandy clay loam sandy clay to sandy loam. According to Landon (1996), the three types of soils named are well drained due to high sand content.

Soil texture is the most stable physical characteristic which influences several other soil properties like soil structure, consistence, soil moisture regime and infiltration rate. Other physical properties influenced by texture are runoff rate, erodibility, workability, permeability, root penetrability and fertility (Landon, 1996).

Nitrates content in soils differs among the soil textures; heavy soils have good water holding capacity due to high porosity which resulted in low leaching. Therefore because of slower drainage and greater potential for denitrification fine textured soils exhibit less nitrate leaching than coarse textured soils (Di and Cameron, 2002; Fan *etal.,* 2010). On the other hand Liu*et al.* (1998) reported higher leaching of nitrates in sandy soils as compared to clayey soils.

Given that the studied soils are mainly sandy in texture it is expected that addition of fertilizers in soils, improper disposal of domestic wastes and improper management of septic tanks will concentrate nitrates in soils which will be leached in underground water.

Table 4:Particle sizeanalysis of the of the selected soils in Singida Urban area

Site	Location on the landscape	Depth (cm)	%Sand	%Silt	%Clay	Textural Class*
Irao	Lower	0-30	68	6	26	SCL
		30-60	52	8	40	SC
		60-100	50	6	44	SC
	Middle	0-30	70	6	24	SCL
		30-60	60	6	34	SCL
		60-100	56	8	36	SC
	Upper	0-30	86	4	10	LS
		30-60	82	4	14	SL
		60-100	76	6	18	SL
Darajani	Lower	0-30	82	6	12	SL
		30-60	84	4	12	LS
		60-100	82	6	12	SL
	Middle	0-30	86	4	10	LS
		30-60	84	4	12	LS
		60-100	82	4	14	SL
	Upper	0-30	84	4	12	LS
		30-60	84	4	12	LS
		60-100	82	4	14	SL
Burudani	Lower	0-30	56	18	26	SCL
		30-60	56	16	28	SCL
		60-100	58	10	32	SCL
	Middle	0-30	62	12	26	SCL
		30-60	54	12	34	SCL
		60-100	nd*	nd	nd	Nd
	Upper	0-30	84	2	14	SL
		30-60	82	6	12	SL
		60-100	82	6	12	SL
Misuna	Lower	0-30	84	4	12	LS
		30-60	80	6	14	SL
		60-100	82	4	14	SL
	Middle	0-30	76	6	18	SL
		30-60	66	6	28	SCL
		60-100	58	8	34	SCL
	Upper	0-30	82	6	12	SL
		30-60	80	6	14	SL
		60-100	80	6	14	SL

*nd = not determined, SCL = Sand Clay Loam, SL = Sandy loam, LS= Loamy Sand

4.2.2 Soil pH, Organic carbon, CEC and electrical conductivity

Selected soil properties including pH, organic carbon content and CEC of the studied soils are presented in Table 5.

Table 5: Some chemical characteristics of the soils of the study area

Study site	Location on the transect	Soil depth (cm)	OC (%)	OM (%)	NO_3 mgkg^{-1} soil	pH		CEC cmol(+)/kg
						In water	KCL	
Irao	Lower	0 – 30	0.97	1.67	109.2	4.9	3.8	8.54
		30-60	0.81	1.39	36.4	4.1	3.2	12.10
		60-100	0.67	1.15	25.2	4.7	3.3	8.70
	Middle	0-30	0.69	1.19	103.6	4.3	3.3	2.82
		30-60	0.65	1.12	30.8	4.4	3.3	3.55
		60-100	0.59	1.01	114.8	5.4	3.7	9.44
	Upper	0-30	0.75	1.29	36.4	4.9	3.8	4.32
		30-60	0.48	0.83	47.6	4.8	3.5	5.06
		60-100	0.51	0.88	58.8	4.7	3.4	6.51
Darajani	Lower	0-30	0.55	0.95	47.6	4.2	3.6	1.67
		30-60	0.46	0.79	53.2	4.8	3.6	3.03
		60-100	0.44	0.75	75.6	5.1	3.6	1.80
	Middle	0-30	0.46	0.79	47.6	4.3	3.5	4.38
		30-60	0.38	0.65	47.6	4.3	5.0	1.92
		60-100	0.36	0.62	47.6	5.0	3.7	1.73
	Upper	0-30	0.49	0.84	58.8	4.5	3.7	1.66
		30-60	0.45	0.77	70.0	4.5	3.6	2.23
		60-100	0.37	0.64	36.4	4.5	3.7	2.89
Burudani	Lower	0-30	2.07	3.56	114.8	7.1	6.5	2.10
		30-60	1.00	1.72	36.4	7.1	6.5	2.89
		60-100	0.69	1.19	25.2	7.2	6.4	2.69
	Middle	0-30	1.63	2.80	25.2	6.7	5.6	2.33
		30-60	0.69	1.19	36.4	6.9	5.5	2.05
	Upper	0-30	0.63	1.08	47.6	6.9	6.0	2.34
		30-60	0.58	1.00	47.6	7.0	5.9	1.99
		60-100	0.34	0.58	25.2	6.6	5.3	2.89
Misuna	Lower	0-30	0.52	0.89	86.8	5.4	3.8	1.68
		30-60	0.58	1.00	36.4	5.5	3.5	1.75
		60-100	0.61	1.05	70.0	5.5	3.4	1.76
	Middle	0-30	0.76	1.31	47.6	5.7	3.9	1.70
		30-60	0.78	1.34	58.8	6.1	4.2	1.78
		60-100	0.61	1.05	25.2	7.3	6.4	1.76
	Upper	0-30	0.68	1.17	103.6	7.3	6.2	1.70
		30-60	0.48	0.83	109.2	7.3	6.1	1.71
		60-100	0.44	0.76	58.8	7.3	5.5	1.58

Soil pH

The results in Table 5 indicate that the pH of the soil in the selected sampling sites in Singida Urban District ranged from 4.1 to 7.3. For example the pH at Irao and Darajani areas ranged from 4.1 to 5.4 and israted as extremely acid to very strong acidic (Brady and Weil, 2008).. On the other hand, areas like Burudani had soil pH ranging from 6.6 to 7.2 which is categorized as neutral (Brady and Weil, 2008). Likewise the pH at Misuna area was 5.4 to 7.3 which is rated as strongly acidic to neutral (Brady and Weil, 2008).

Generally pH values of the studied soils were quite variable. The topsoils had pH values ranging from 4.2 to 7.3 while the sub-soils had values ranging from 4.7 to 7.3. There was no clear trend of pH variability between topsoils and sub-soils because at some instances pH increased with depth and in some areas it decreases with depth. Burudani areas for example had values ranging from 6.7 to 7.1 in topsoils and 6.6 to 7.2 in sub-oils. This area however, had higher levels of nitrates as compared to others due to higher organic matter contents and the microbial decomposition of NH_4^+ from organic matter is very rapid in that pH range.

Soil pH plays an important role in as far as the microbial processes of the soil are concerned. At pH near neutral (pH 7), the microbial conversion of NH_4^+ to nitrate (nitrification) is rapid, and crops generally take up nitrate (Brady and Weil, 2008). This implies that the buildup of nitrates is higher ranging from 6.5 to 7.5. In acid soils ($pH < 6$), nitrification is slow hence accumulation of nitrate is very low thus plants with the ability to take up NH_4^+ may have an advantage (Brady and Weil, 2008).

Furthermore the electrical conductivity within the study area ranged from 0.03 to 0.77 and is rated as non saline (Landon, 1996). This implies that the area has no salinity problems.

Organic carbon

Generally organic matter levels (SOM) in the surveyed sites were very low to medium, ranging from 0.6 to 3.6 (Landon, 1996). The topsoils had values ranging from 0.79 to 3.56 while the sub-soils ranged from 0.62 to 1.19 (Table 5). The trend of SOM variability from the topsoils to sub-soils was clear since the levels decreased with depths along the profile. Despite the fact that there was no clear relationship between soil organic matter contents and nitrate levels in soils, Burudani area had shown a positive relationship between nitrate levels and soil organic matter as such, the levels of nitrates in surface soils at Burudani area were higher as compared to other areas due to rapid decomposition of soil organic matter.

Low to medium levels of soil organic matter in soils accounts for low fertility status and poor water holding capacity of the studied soils (Hudson, 1994). Poor water holding capacity of the soils may encourage high leaching of nutrients including nitrates from the topsoils to the subsoils. This accounts for the low levels of nitrates in the surface soil. These results are in agreement with the data reported by Tisdale *et al.*(1993).

Cation exchange capacity (CEC)

Laboratory results indicated that cation exchange capacity (CEC)of the soil in surveyed sites was very low to low ranging from 1.58 to 12.10 cmol (+) kg^{-1}soil. According to Landon (1996), CEC values less than 15 cmol (+) kg^{-1}is considered to be low, while 15 to 25 cmol (+) kg^{-1} medium and 25 to 40 cmol (+) kg^{-1} is considered high. Very low to low CEC values observed in the study areacould be the result of low organic matter contents and high contents of sand. The results also imply that fertility status of the soil is low. High contents of sand and low organic matter contents imply poor buffering capacity of the soils (Namakka *et al.,* 2014). Poor buffering results into leaching of soluble nutrients out of the rooting zone.

4.3 Nitrate Levels in Water and in Soils

Figure 2 shows nitrate levels in water and surface soilsof the studied sampling sites in the study area.

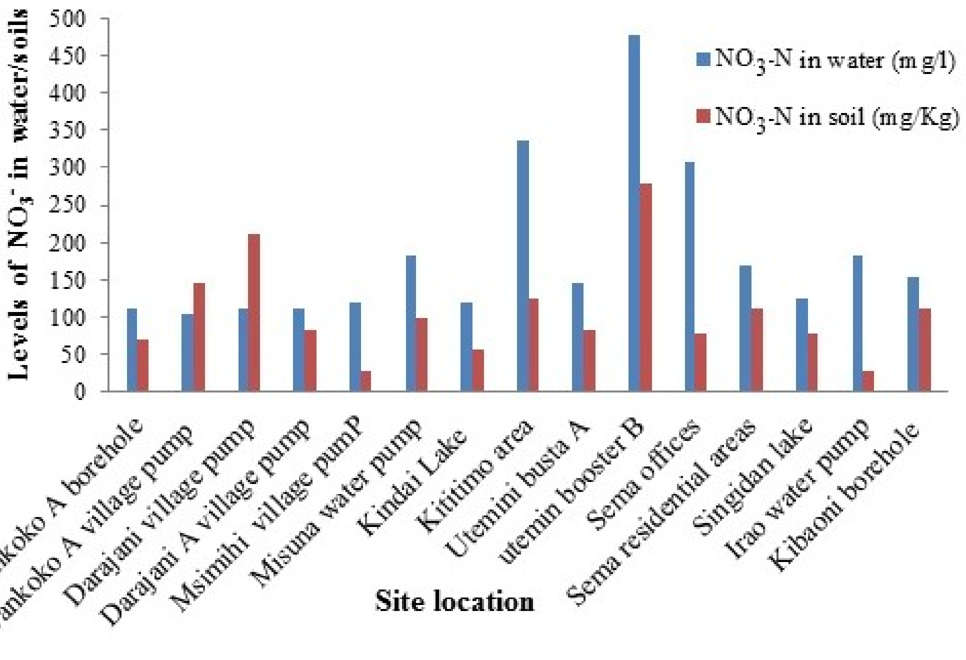

Figure 2: Nitrate levels in water and surface soilsof selected sites

4.3.1Nitrate levels in water

Results in Figure 2show that nitrate levels in water in thestudied siteswere above the maximum recommended standard of $50mgL^{-1}$ as described by WHO (2007) and of $20mgL^{-1}$ as per TBS (2005) and EMA (2007) standards. Burudani area recorded the highest levels of nitrate ($476mgL^{-1}$) while Mwankoko A village pumping station recorded the lowest levels of nitrate in water($105mgL^{-1}$). It is clear from the results that the water sources in the studied sites were not only unsafe for human but also for animal consumption. The observed nitratelevelswere higher than that of 65.4 - 322 mgL^{-1} as reported by Kongola *et al.* (1999) within the same area.

The resultsin Figure 2 imply that seasonal application of fertilizers could influence the increase in nitrate levels in water. The results from this study has been supported by the study that was conducted by Rwebusiga (2008) on nitrate levels in Makutupora well fields in Dodoma Region within the same internal drainage basinshowed that the levels of nitrates increasedover time. The increase of nitrates levels with time may be associated with human activities particularly agriculture, application of fertilizers, improper treatment of sewage systems as the improper disposal of domestic and industrial wastes.

The Study conducted by Nkotagu (1996)indicated that nitrate concentrations in groundwater samples collected at Hombolo sub-basin in the same internal drainage basin ranged from 0.01 to 449.1mgL^{-1} with a median of 52.8 mgL^{-1}. The results further indicated that 50 % of water samples had nitrate concentration higher than the maximum concentration recommended for drinking by WHO (2007), while 76 % of the samples had nitrate concentrations above background concentration of 10 mgL^{-1}(Nkotagu, 1996). Such data indicated that about 76 % of the water samples were contaminated by nitrate resulting from human activities specifically onsite sanitation (particularly pit latrines) and animal manure since the area was occupied by pastoralists, and there was an insignificant application of industrial fertilizers.

Therefore based on observation by Nkotagu (1996), it is clear that high levels of nitrates in water in the studied area might also be attributed to human activities particularly agriculture. Leaching of nutrients especially N could be another reason for the increased concentration of nitrates in underground water.

4.3.2 Nitrate levels in topsoils

Results on nitrate levels in topsoils around water sources are also presented in figure 2. Based on the results Burudani (Utemini Booster) area had higher level of nitrate while Irao area had the lowest level of nitrate. High levels of nitrate in topsoils may be attributed to human activities (agriculture) carried in the area. The use of agricultural inputs (fertilizers), disposal of municipal and domestic wastes, lateral movement of nitrates from the upper slopes as well as poor drainage could be associated with the observed levels of nitrate in the studied sites.

4.4 Variation of Soil Nitrate Levels with Depth and Location on a Toposequence

The findings on the distribution of nitrates in soils close to water sources are indicated in Figure 3, 4 and 5.

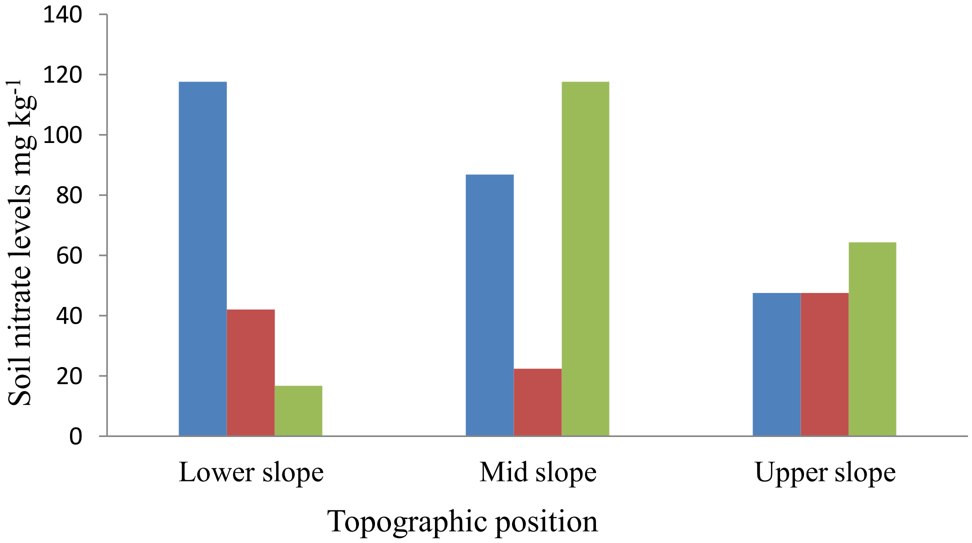

Figure 3: Variation of soil nitrate levels with depth along a toposequence in Irao

Soil nitrate distribution along the topographic gradient (Fig 3) showsa decline with increasing elevation in the topsoil. There is no clear trend of nitrate variability in the subsoil depth (30 cm – 60 cm) thus showing a reverse order in deeper horizon. The observed trends could be attributed to surface runoff and lateral movement of nitrates from the upper slope to the lower surface. Leaching of nitrates from the topsoils of the upper slope to the sub-soils of the mid slope could be attributed to the observed trend in deeper horizon.

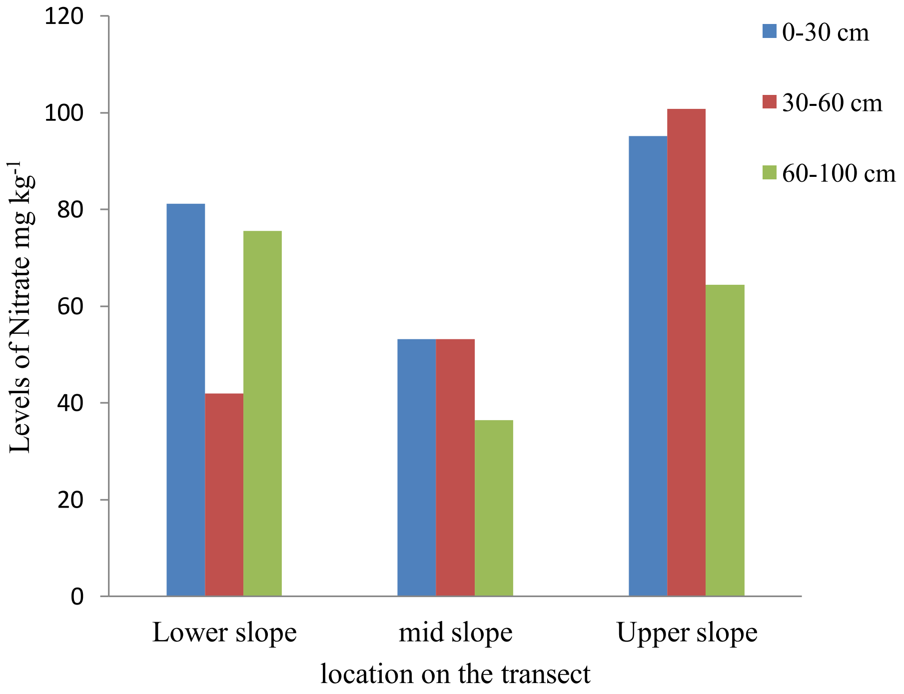

Figure 4: Variation of soil nitrate levels with depth along a toposequence in Misuna

Soil nitrate levels (Fig. 4)are higher in topsoils and subsoils as well as the lower and upper slope positions. The observed trend could be a result of human activities (agriculture) involving the application of fertilizers and surface runoff from the upper slopes to the lower slopes. Leaching of nutrients (nitrates) into deeper horizon could also attribute the observed trend in the sub-soil.

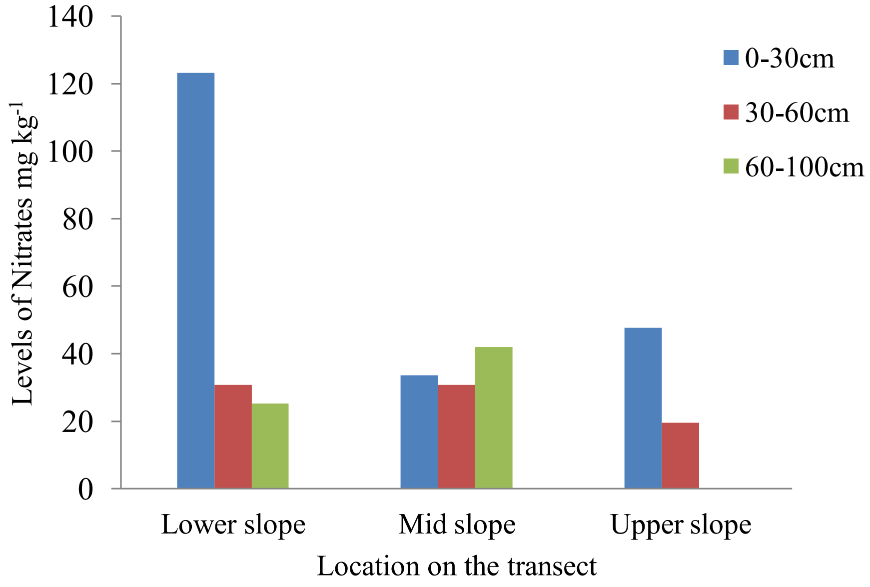

Figure 5: Variation ofsoil nitrate levels with depth along a toposequencein Utemini booster B

The results from the studied site (Fig. 5) show that, the topsoil of the lower slope had higher soil nitrate levels compared to other topographic positions. The observed trend could be associated with human activities (agriculture) involving application of fertilizers, disposal of domestic wastes as well as discharges from septic systems on the topsoils while poor drainage could be attribute to the observed trend in other topographic positions within the site.

Generally from the figures 3, 4 and 5 it is clear thatthe topsoils near the water sources (lower slopes) had highernitrate levels than the upper slopes. Higher levels of nitrates in the lower slopes could be associated with surface runoff from the upstream especially during rainy seasons and lateral drainagebecause the sitesare dominated by sandy soils which allow easy drainage (Brady and Weil, 2008).

Variations of nitrate levels in the studied sites also might have been due to biological composition of the soils as well as the physical chemical properties and hydrogeology of the surveyed area. Mtoni (2013) reported a decreasing trend of nitrate concentration in groundwater as the depth of the well increases. Furthermore Kibona *et al*. (2011) reported a significant negative correlation between nitrate concentration and well depth where the highest concentration of nitrate was observed in the upper surfaces and the concentration decreasedas the depth of the well increased. According to Kibona*et al.* (2011), the decrease in nitrate concentration with depth was attributed by the anoxic condition that is common in deep wells. In anoxic condition, nitrate is the electron acceptor of choice, hence easily reduced. With little or no oxygen, microorganisms use nitrate as an electron acceptor to oxidise organic carbon (Kibona *et al*., 2011).

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Based on the findings of this study, it is concluded that:

i) Nitrate levels in water in the selected locations in Singida Urban District ranges from 105 mgL^{-1} to 476 mgL^{-1}, the values which are above the maximum recommended standard of 50 mgL^{-1} as described by WHO (2007) and of 20 mgL^{-1} as per TBS (2005) and EMA (2007),thuslong term consumption by human beings and animals without treatment to reduce levels of nitrates may result in health problems in human and animals in the area.

ii) Nitrate levels in soils rangedfrom 25.2 $mgkg^{-1}$to 114.8 $mgkg^{-1}$soils,thevalues which are within the tolerablelimits as far as agriculture is concerned. However,highest levels of nitrates in soils were observed in areas surrounding the water sources probably as a result of surface runoff from the up streams

iii) The distribution of nitrate in soils with depth and toposequence were such that; along topographic gradient the levels were higher on the lower slope and decreases with altitude. With depth the levels were such that higher values were observed on the topsoils and decreases with increasing depthprobably due to agricultural activities on the surface soils including the use of fertilizers.

iv) Highlevels of nitrates in water in the study area resulted from human activities particularly waste disposal,the use of natural agricultural inputs(animal manure)and crop residuals.

5.2 Recommendations

Based on the findings of this study, the following recommendations are given;

i) Since both underground and surface water samples had high nitrate levels above the recommended levels for domestic uses, it is recommended that alternative safe water resources for human and livestock consumption be explored.

ii) High levels of nitrates in water was recorded in stations like Utemini booster B (Burudani), Kititimo and Sema offices it is then accommodated that water from these areas should not be used for domestic activities.

iii) Further studyon the dynamics of soil nitrates in Singida District is recommended in order to identify areas which are highly polluted by nitrates. This study should be carried out throughout the year so as to determine the dynamics of nitrates in water and soils by seasons

iv) To minimize the risk factors associated with nitrate pollution which arecarcinogenic, researchers should come up with technologies including the use of microorganisms in order to reduce high nitrate levels in drinking water.

REFERENCES

Addiscott, T. M. (2005). *Nitrate, Agriculture and the Environment*. Commonwealth for Agriculture Bureau International, Wallingford. 279pp.

Agrawal, G. D., Lunkad, S. K. and Malkhed, T. (1999). Diffuse agricultural nitrate pollution of groundwaters. *Water Science Technology India* 39: 67–75.

Bakari, S.S. Aagaard, P., Vogt, R. D., Ruden, F., Johansen, I. and Vuai S. A. (2012). Delineation of groundwater provenance in a coastal aquifer using statistical and isotopic methods, Southeast Tanzania. *Environmental Earth Science* 66: 889 – 902.

Barbooti, M. M., Bolzoni, G., Mirza, I. A., Pelosi, M., Barilli, I., Kadhum, R. and Peterlongo, G. (2010). Evaluation of quality of drinking water from Baghdad, Iraq. *Science World Journal* 5(2): 35 – 46.

Benson, V. W., Potter, K. N., Bogusch, H. C., Goss, D. and Williams, J. R. (1992). Nitrogen leaching sensitivity to evaporation and soil storage estimates in EPIC. *Journal of Soil and Water Conservation* 47(4): 334 – 337..

Bowell, R. J., Robertson, S., Walles, K., Bwankuzo, M. A., Cowan, J., Kimaro, N., Mjengera, H. A., Terkhell, K., Warren, A. and Wood, A. (1997). Improving water quality assessment and supply. In: *Water and Sanitation for All: Partnerships and Innovations.Proceedings of the 23rd WEDC Conference,* (Edited by Pickford, J.), Durban, South Africa. pp. 146 – 149.

Brady, N. C. and Weil, R. R. (2008). *The Nature and Properties of Soils.* (14th Ed.), Pearson Prentice Hall, New Jersey, USA. 610pp.

Bremner, J. M. and Keeney, D. R. (1966). Determination and isotope - ratio analysis of different forms of nitrogen in soil: Exchangeable ammonium, nitrate, and nitrite by extraction-distillation methods. *Soil Science Society of America Proceedings* 30(5): 577 – 582.

Bremner, J. M. and Mulvaney, C. S. (1982). Total Nitrogen. In: *Methods of Soil Analysis Part 2: Chemical and Microbiological Properties*. (Edited by Page, A. L., R. H., Miller, R. H. and Keeney, D. R.), American Society of Agronomy, Madison, Wisconsin, USA. pp. 890 – 902.

Bremner, J. M. and Shaw, K. (2005). Determination of ammonium nitrate in soil. *The Journal of Agricultural Sciences* 46(3): 320 – 328.

Burkholder, J. M. (1998). Implications of harmful microalgae and heterotrophic dinoflagellates in management of sustainable fisheries. *Ecology Applied* 8: 37–62.

Chapman, H. D. (1965). Cation Exchange Capacity. In*: Methods of Soil Analysis*. (Edited by Blac, C. A., Evance, D. D., Ensiminger, L., Clark, F. E. and White, J. L.) American Society of Agronony, Madison, Wisconsin. pp. 891 – 901.

Chiu, H. F., Tsai, S. S. and Yang, C. Y. (2007).Nitrate in Drinking Water and Risk of Death from Bladder Cancer: An ecological case-control study in Taiwan.*Journal of Toxicology and Environmental Health*70: 1000 - 1004.

Crohn, D. (2004). Nitrogen mineralization and its importance in organic waste recycling In: *Proceedings, National Alfalfa Symposium*, San diego, USA. 13 – 15 pp.

Dave, W., Angela, P., Hillary, C and Steve, H. (2013). *Nitrogen in Water*; *Formsand Concerns.* Minnesota. 22pp.

de Ruijter, F. J., Boumans, L. J. M., Smit, A. L. and van den Berg, M. (2007). Nitrate in upper groundwater on farms under tillage as affected by fertilizer use, soil type and groundwater table. *Nutrient Cycling in Agroecosystems* 77: 155 - 167.

Di, H. and Cameron, K. (2002). Nitrate leaching in temperate agroecosystems: Sources, Factors and Mitigating strategies. *Nutrition cycling Agroecosystem* 64: 237 – 256.

Duursma, E. K. and Dawson, R. (Eds) (1981). *Marine organic chemistry*: *Evolution, composition, interactions and chemistry of organic matter in seawater*. Elsevier, Amsterdam. 521pp.

EMA (2007). Water quality standards. *Permissible Limits for Municipal and Industrial Effluents* 8: 19 – 21.

Fan, J., Hao, M. and Malhi, S. S. (2010). Accumulation of nitrates in the soil profile and its implications for the environment under dry land agriculture. China. A review. *Canadian Journal of Soil Science* 90: 429 – 440.

Fields, S. (2004). Global nitrogen: Cycling out of control. *Environmental Health Perspective* 112: 557 – 563.

Galvis-spinola, A., Alvarez-sanchez, E. and Etchevers, B. D. J. (1998). A method to quantity N fertilizer requirement. *Nutrient Cycling in Agro ecosystems* 51: 155 – 162.

Gatseva, P. D. and Argirova, M. D. (2008). High-nitrate levels in drinking water may be a risk factor for thyroid dysfunction in children and pregnant women. *International Journal of Hygiene and Environmental Health* 211(5): 555 – 559.

Gee, G. W., Bauder, J. W. and Klute, A. (1986). Particle-size analysis. In: Methods of soil analysis part 1: *Physical and Mineralogical Methods* 5: 383 – 411.

Hajek, B. F., Karlen, D. L., Lowery, B., Power, J. F., Schumacer, T. E., Skidmore, E. L. and Sojka, R. E. (1990). Erosion and soil properties. *Advances in Agronomy* 15: 119 – 159.

Halvin, J. L., Beaton, J., Tisdale, S. L. and Nelson, W. L. (2005). *Soil Fertility and Fertilizers: an Introduction to Nutrient Management*. (7th Ed.), Pearson Education, Inc., Upper Saddle River, New Jersey. 515pp.

Hudson, B. D. (1994). Soil organic matter and available water capacity. *Journal of Soil and Water Conservation* 49: 180 – 194.

Hynes, R. J. and Naidu, R. (1998). Influence of Lime, Fertilizers and manure application on soil organic matter contents and soil physical conditions. *Nutrient Cycling In Agroecosystems* 51: 123 – 137.

James, D. W. and Topper, K. F. (1993). Utah fertilizer guide. Utah. [http://digitalc ommons.usu.edu/extension_histall/19] site visited on 4/11/2016.

Jiban, S. M., Davis, D., Somashekar, R. K., Prakash, K. L. and Shivanna, K. (2010). Environmental isotopes investigation in groundwater of Challaghatta valley, Bangalore: *Journal of Environmental Science and Technology* 4(4): 226 – 233.

JICA (2008). *The Study on the Groundwater Resources Development and Management in the Internal Drainage Basin in the United Republic of Tanzania*. Ministry of Water and Irrigation. Dar es Salaam, Tanzania. 93pp.

Johnson, C., Albrecht, G., Ketterings, Q., Beckman, J. and Stockin, K. (2005). *Nutrient Management Spear Program: Nitrogen Basics*. Cornell University Cooperative Extension, New York, USA. 2pp.

Jones, C. A., Koenig, R. T., Jason, W. E., Brown, B. D. and Jackson, G. D. (2012). Management of urea fertilizer to minimize volatilization. [http://www. extension.uidaho.edu/swidaho/nutrient%20management/pnwureamanagement.pdf] site visited on 4/11/2016.

Kashaigili, J. J. and Majaliwa, A. M. (2010). Integrated assessment of land use and cover changes in the Malagarasi river catchment. Tanzania. *Physical Chemistry* 35: 730 – 741.

Kibona, I., Mkoma, S. L. and Mjemah, I. C. (2011). Nitrate pollution of Neogene alluvium aquifer in Morogoro municipality, Tanzania. *International Journal of Biological Chemical Science* 5: 171–179.

Killpack, S. C. and Buchholz, D. (1993). Nitrogen in the Environment: Ammonia Volatilization. University of Missouri Extension, Missouri.

Kongola, L.R.E., Nsanya, G., and Sadiki, H. (1999). Groundwater resources: development and management, an input to the Water Resources Management Policy Review (Draft), Dar es Salaam. [https://pure.tue.nl/ws/files/2386306/200211708.pdf]site visited on 4/11/2016.

Korsaeth, A. and Eltun, R. (2000). Nitrogen mass balances in conventional, integrated and ecological cropping systems and the relationship between balance calculations and nitrogen runoff Norway. *Agriculture, Ecosystems and Environment*79: 199 – 214.

Lamb, J. L., Fernandez, F. G. and Kaiser, D. E. (2014). Understanding nitrogen in Soils. University of Minnesota. [www.extension.umn.edu/agriculture/nutrientmanagement] site visited on 22/06/2015.

Landon, J. R. (1996). *Booker Tropical Soil Manual*: *A handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics*. Longman Publisher, Sussex. 474pp.

Lashgaripour, G. H. and Ghafoori, M. (2001). Nitrate in Mashad's underground waters. *Journal of Water and Wastewater* 41: 2 – 7.

Liu, D. Q., Tang, Y. A., Sun, B. H. and Emteryd, O. (1998). Study on effects of nitrogen fertilizer use on Environmental pollution. *Plant Nutrition fertile Science* 4: 8 – 15.

Mato, R. R. A. M. (2002). *Groundwater Pollution in Urban.* Technical University of Eindhoven, Dar es Salaam, Tanzania. 215pp.

McLean, E. O. (1982). Soil pH and lime requirement. In: *Methods of Soil Analysis Part 2: Chemical and Microbiological Properties*. (Edited by Page, A. L., Miller, R. H. and Keeney, D. R.), America Society of Agronomy, Madison, Wisconsin. pp. 199 – 224.

MDA (2011). *Water Quality Monitoring Report*. Report No.100. Minnesota Department of Agriculture, Minnesota. 199pp.

Mitsch, W. J., Day, J. W., Gilliam, J. W., Groffman, P. M., Hey, D. L., Randall, G. W. and Wang, N. (2001) Reducing nitrogen loading to the gulf of Mexico from the Mississippi River Basin: strategies to counter a persistent ecological problem. *BioScience* 51: 373 – 388.

Mjemah, I. C. (2007). *Hydrogeological and Hydrogeochemical Investigation of a Coastal Aquifer in Dar es Salaam.* University of Gent, Belgium. 222pp.

Moberg, J. R. (2000). *Soil and Plant Analysis Manual*. The Royal Veterinary and Agricultural University, Chemistry Department, Copenhagen, Denmark. 133pp..

Mtoni, Y. E. (2013). *Salt Water Intrusion in the Coastal Strip of Dar es Salaam Quaternary Aquifer.* University of Gent, Tanzania. 395pp.

Mtoni, Y. E., Mjemah, I., Msindai, K., Van Camp, M. and Walraevens, K. (2012) Saltwater intrusion in the Quaternary aquifer of the Dar es Salaam, Tanzania. *Geologica Belgica* 15: 16 – 25.

Mwinuka, C. T. K. J. (2001). The influence of selected cropping systems on soil properties in Kwalei village, Lushoto, Tanzania. Dissertation for Award of MSc Degree at Sokoine University of Agriculture, Morogoro, Tanzania, 122pp.

Namakka, A., Hassan, A. H., Ahmad S. M., Lere, G. A. and Sharifai, A. I. (2014). Effect of tillage system on soil properties and yield of Oba maize variety in Zaria. *Net Journal of Agriculture Science* 2(3): 89 – 93.

National Beural of Statistics (2012). *Population and Housing Census Report.* The United Republic of Tanzania. 264pp.

Nelson, D. W. and Sommers, L. E. (1982). Total carbon, organic carbon and organic matter. In: *Methods of Soil Analysis Part 2.* (Edited by Page, A. L., Miller, R. H. and Keeney, D. R.), American Society of Agronomy, Madison, Wisconsin. pp. 539 – 579.

Nkotagu, H. (1996). Origins of high nitrate in groundwater in Tanzania. *Journal of Africa Earth Science* 22: 471 – 478.

Oenema, O., Boers, P. C. M. and Van, M. M. (1998). Leaching of nitrate from agriculture to groundwater: the effect of policies and measures in the Netherlands. *Environmental Pollution* 102: 471 – 478.

Orebiyi, E. O., Awomeso, A. J., Martins, O., Idowu, A. O., Oguntoke. O. and Taiwo, A. M. (2010). Assessment of pollution hazards of shallow well water in abeokuta and environs. *American Journal of Environmental Science* 6(1): 50 – 56.

Petro, F., Key, R., Maganga, Z. and Lema, F. (2014). *Geological Map of Singida Quarter Degree Sheet 102*. Geological survey, Tanzania. 1pp.

Pittalis, D. (2010). Interdisciplinary studies for the knowledge of the groundwater fluoride contamination in the eastern African rift: Meru District-North Tanzania. Thesis for Award of PhD Degree at University of Sassari. 102pp.

Provin, T. L. and Hossner, L.R. (2001). *What Happens to Nitrogen in Soils?.*AgriLife Extension Service A and M System. USA. 4pp.

Randall, G. W., Huggins, D. R., Russelle, M. P., Fuchs, D. J., Nelson, W. W. and Anderson, J. L. (1997). Nitrate losses through subsurface tile drainage in conservation reserve program, alfalfa and row crop systems. *Journal of Environment Quality* 26: 1240 – 1247.

Razowska-Jaworek, L. and Sadurski, A. (Eds) (2005). *Nitrates in Groundwater: IAH Selected Papers on Hydrogeology*. CRC Press, USA. 258pp.

Reddy, K. R., Patrick, W. H. and Lindau, C. W. (1989). Nitrification-denitrification at the plant root-sediment interface in wetlands. *Limnology Oceanograph* 34:1004 – 1013.

Riffald, R., Saviozzi, A., Aevi, M. R. and Menchetti, F. (1994). Chemical characteristics of soils after forty years of continuous maize cultivation. *Agriculture Ecosystems and Environment* 40: 239 – 245.

Robertson, G. P. and Groffman, P.M. (2007). Nitrogen transformations. *Soil Microbiology, Ecology, and Biochemistry* 3: 341 – 364.

Rwebugisa, R. A. (2008). *Groundwater Re-Charges Assessment in the Makutupora Basin, Dodoma, Tanzania.* International Institute for Geo-Information Science and Earth Observation, Enschede, Netherland. 111pp.

Sharma, K. L., Srinivas, K., Mandal, U. K., Ramakrishna, Y. S., Vittal, K. P. R., Das, S.K., Martin, D., Grace, J. K. and Balloli, S. S. (2007). Kinetics of decomposition of un-conventional farm-based crop residues and their composting and quality monitoring. *Communications in Soil Science and Plant Analysis* 38(18): 2423 – 2444.

Spalding, R. F. and Exner, M. E. (1993). Occurrence of nitrate in groundwater, A review. *Journal of Environmental Quality* 22: 392 – 402.

Swai, O. W., Mbwambo, J. S. and Magayane, F. T. (2012). Perceived effects of climate change on agricultural production: A Gendered Analysis Done in Bahi and Kondoa Districts, Dodoma Region, Tanzania. *Research on Humanities and Social Sciences* 2(9): 59 – 68.

TBS (2005). *National Environmental Standards Compendium:* Tanzania Bureau of Standards, Dar es Salaam, Tanzania. 10pp.

Tisdale, S. L., Nelson, W. L., Beaton, J. D. and Halvin. J. L. (1993). *Soil Fertility and Fertilizers*. Fifth Edition. MacMillan Publishing Company. New York. 634pp.

Undersander, D., Combs, D., Howard, T., Shaver, R., Siemens, M. and Thomas, D. (1999). *Nitrate Poisoning in Cattle, Sheep and Goat.* Madison Extension Cooperative Service*,* Madison,Wisconsin. 8pp.

Vaje, P. I., Singh, B. R. and Lal, R. (1999). Erosion effects on nitrogen balance in maize (*Zea mays.*L) grown on a volcanic ash soil in Tanzania. *Nutrient Cycling in Agro ecosystems* 54: 113 – 123.

Vitosh, M. L., Johnson, J. W. and Mengel, D. B. (eds) (1995). *Tri -state Fertilizer Recommendations for Corn, Soybeans, Wheat and Alfalfa.* Ohio, Michigan, USA. 24pp.

Ward, M. H. (2009). Too much of a good thing? Nitrate from nitrogen fertilizers and cancer. *Reviews on Environmental Health* 24(4): 357 – 363.

Ward, M. H., deKok, T. M., Levallois, P., Brender, J., Gulis, G., Nolan, B. T. and Van Derslice, J. (2005). Workgroup report: Drinking-water nitrate and health Recent findings and research needs. *Environmental Health Perspective* 113: 1607–1614.

Wells, K. L., Thomas, G. W., Sims, J. L. and Smith, M. S. (1991). Managing soil nitrates for agronomic efficiency and environmental protection. [www2.ca.u ky.edu/agc/pubs/agr/agr147/agr147.htm] site visited on 13/6/2015.

WHO (2007). Nitrate and nitrite in drinking water. Geneva, Switzerland.[www.who.int/ water_sanitation_health/dwq/chemi cals/nitraten itrite2ndadd.pdf] site visited on 10/6/2016.

Wick, K., Heumesser, C. and Schmid, E. (2012). Groundwater nitrate contamination: factors and indicators. *Journal of Environmental Management*111(3): 178 – 186.

Yang, C. Y., Tsai, S. S. and Chiu, H. F. (2009). Nitrate in drinking water and risk of death from pancreatic cancer in Taiwan. *Journal of Toxicology and EnvironmentalHealth* 72: 397 – 401.

APPENDIX

Appendix 1: Questionnaire on social economic activities performed by Singida Municipal residents

1. What activities are you engaged in?
    a) Crop cultivation
    b) Livestock keeping
    c) Small scale mining
    d) Crop cultivation and livestock keeping
    e) a,b,c
    f) Others (name)………..
2. What type of crops do you grow?
    a) Beans
    b) Maize
    c) Finger millet
    d) Sunflower
    e) a,b
    f) a,b,c
    g) a,b,c and d
3. In the crops you named above are you applying fertilizer?
    a) Yes
    b) No
4. If your answer in (3) is yes then what type of fertilizer?
    a) Urea
    b) N.P.K
    c) T.S.P

   d) Manure
   e) Others (name)
5. How much do you apply per hectare? (name)……………………
6. How many times (frequency) do you apply per growing season?
   a) Once
   b) Twice
   c) Others (name)
7. When do you apply your fertilizer?
   a) Before planting
   b) After planting
8. If your answer in (3) is no why?
9. Do you know any industry within the municipal?
   a) Yes
   b) No
10. If yes what type of industry?
11. What are the chemicals/ products released
12. Where are the chemicals disposed off?
13. Where do you dispose your domestic wastes?