EFFECT OF CHEMICAL FERTILIZER ON GROUNDWATER QUALITY IN AN UNCONFINED AQUIFER

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ABSTRACT

The use of fertilizer on soil in order to improve agricultural yield has been practiced for years. While fertilizers and manures greatly improve crop yield, it is also important to consider the corresponding and devastating effects. In this study, the fertilizers application rate was varied and their effects on groundwater quality with soil depths of 30cm and 60cm was observed. Two fabricated lysimeters was used to collect soil samples undisturbed and taken to the laboratory for analyses. The samples in the lysimeters was made saturated and varying quantities of fertilizers from 87.37g and 100g were applied. The saturation of the samples was done through an improvised rainfall simulator which was set up in such a way that a constant discharge was adopted. Water samples were collected at 30cm and 60cm depths and analyzed for fertilizer residues and physico-chemical characteristics such as temperature, pH, total chloride, total dissolved solids, dissolved oxygen, conductivity, free ammonia, total phosphate, urea, zinc and iron. The results showed that the more the quantities of fertilizers applied on the soil, the more it affects the physico-chemical properties of the water and renders it toxic and unsuitable for drinking purposes except treated. The results, however revealed that the concentrations of the fertilizers in the groundwater decreases with soil depths.

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ABBREVIATIONS

Abbreviations	Full Meaning
EPA	Environmental Protection Agency
GIS	Geographic Information System
NDMR	New Duncan Multiple Range
NPS	Non-Point Source
AFO	Animal Feeding Operation
CAFO	Concentrated Animal Feeding Operation
TSS	Total Suspended Solids
TDS	Total Dissolved Solid

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

The use of fertilizer on soil in order to improve agricultural yield has been practiced for years. While fertilizers and manures greatly improve crop yield, it is important to consider the corresponding and devastating effects of fertilizer leaching from agricultural soil into groundwater and surface water which causes a major environmental and public health concern. This is purely as a result of indiscriminate use of these agro-chemicals on crops for the sake of agricultural productivity. Chemical fertilizers are relatively inexpensive, have high nutrient contents, and are rapidly taken up by plants. However, the use of excess fertilizer can result in a number of problems, such as nutrient loss, surface water and groundwater contamination, soil acidification or basification, reductions in useful microbial communities, and increased sensitivity to harmful insects (Chen 2006). This in other words, means there is need for the knowledge of optimum use of agro-chemicals that will guarantee agricultural productivity and at the same time enhance safety of groundwater body. Several works have been carried out in-situ detailing the influence of agro-chemicals such as fertilizers, in particularly on groundwater resources (Anim-Gyampo et al., 2019; Ashraf et al., 2019; Bhushan & Pathma, 2021).

Chand et al. (2006) have reported that the mixed use of nitrogen–phosphorus–potassium (NPK) chemical fertilizer and livestock organic manure increases the mean growth of mint (Mentha arvensis) and mustard (Brassica juncea) by 46% and the soil concentrations of nitrogen, phosphorus, and potassium by 36%, 129%, and 65%, respectively.

Various degrees of successes have been recorded in observing the traces of these chemicals deep beneath the soil surface to as deep as 3-4 m, even with those studies carried out in the laboratory. Kaur et al. (2005) compared the use of chemical fertilizer treatment only and mixed chemical fertilizer and organic manure treatment in farmland rotating sorghum (Pennisetum glaucum) and wheat (Triticum aestivum), and found that organic manure increased the soil concentrations of organic carbon, nitrogen, phosphorus, and potassium, thus highlighting its importance in tropical farmland, which lacks organic matter. A study on tomatoes (Lycopersicon esculentum) and corn (Zea mays) in acidic soil by Murmu et al. (2013) found that organic manure increases crop productivity, nitrogen utilization efficiency, and soil health compared to chemical fertilizer.

In a study on a short-rotation willow (Salix dasyclados) plantation that was carried out to maximize biomass production in the middle east region of North America, using slow-acting chemical fertilizer and organic livestock manure, the organic manure treatment markedly increased the growth of the willow, the pH at a soil depth of 0–10 cm by 2, and soil concentrations of potassium, phosphorus, and magnesium (Adegbidi et al. 2003). However, Larcheveque et al. (2011) found that chemical fertilizers promote higher growth and root development compared to livestock organic manure in a poplar plantation in clay soil.

Studies on the optimum use of fertilizers have not been given considerable attentions in the past and therefore will be worthwhile if given adequate attention in order to save our groundwater bodies while still maintaining agricultural productivity. In this study, three fabricated lysimeters will be used to collect soil samples undisturbed and taken to the laboratory for further studies and examinations. The samples in the lysimeters will be

saturated and varying concentrations of fertilizers applied. The saturation of the samples will be done through rainfall simulator at a constant discharge. For each saturation processes through rainfall simulator, water samples will be collected at various depths and analyzed for fertilizer residues and physico-chemical characteristics.

This study will help to determine the effect of fertilizer leaching on ground water as well as the appropriate optimum quantities of fertilizer that should be applied to minimize the negative impact on the environment and human health. Among the results expected of this study are; Variation of physico-chemical characteristics of fertilizers in ground water. Graphs showing various characteristics of the water samples varied with soil depth, concentration of PO_4 at various depths of the soil core in the lysimeters, concentration of NO_3 at various depths of the soil core in the lysimeters, concentration of turbidity at various depths of the soil core, comparison of mean of physical and bacteriological parameters using New Duncan Multiple Range (NDMR) test and concentration of total coliform at various depths of the soil core. Also, is the average heavy metals contents of the water samples as they vary with soil depth, hydraulic conductivities of the soil samples at various depths of 30 cm, 60 cm and 90 cm, correlation of soil permeability with groundwater pollution, optimum fertilizers application for sustainable agriculture and safe groundwater, sieve analysis of the soils within the study area and the statistical analysis of physico-chemical characteristics with fertilizer residues. The total period of 12 months will be needed for the successful completion of this study.

The severe impact of the fertilizers leaching on water quality especially where there is groundwater exploration for human use or for irrigation purposes and the influence of rainfall on fertilizers movement within the soil mass are parts of the results expected.

Groundwater is an important source of water supply for municipalities, agriculture and industry. Therefore, the capability to predict the behavior of chemical contaminates in flowing groundwater is of vital importance for a). The reliable assessment of hazardous or risks arising from groundwater contamination problems, and b) the design of efficient and effective techniques to mitigate them. There are several studies reported in this filed. Reliable and quantitative prediction of contaminant movement can be made only if we understand the processes controlling the transport of contaminants. These include a) advection, b) hydrodynamic dispersion and c) physical, chemical and biological reactions that affect their soluble concentrations in groundwater.

While the use of agro-chemicals to improve agricultural yield is very important, and has been in practice for many years, recent research has shown concern on the corresponding negative impact it has on the environment especially in surface and groundwater. As such chemicals are mostly water soluble, they contaminate water bodies, and groundwater which is now a major problem as humans and animals rely on them for sustenance. In this study, the effect of fertilizer leaching in groundwater is investigated.

Fertilization increases productivity and obtains better quality of product recovery in agricultural undertakings. Though, there are many other methods of achieving this, but Fertilization is one of the most essential methods. Inorganic agrochemical, like fertilizers mostly contain nitrate, phosphate, potassium and ammonium salts. Fertilizer industry is adjudged to be one of the main sources of natural radionuclides and heavy metals. As a potential source, according to Savci (2012). Fertilizers contain a vast majority of the heavy metals like Pb, Ni, Hg, As, Cd, Cu, and Ni; natural radionuclide like ^{210}Po, ^{32}Th, and ^{238}U.

However, in recent years, consumption of fertilizer increased considerably in the world over, and as a result, this causes serious environmental problems. Fertilizer application may affect the accumulation of heavy metals in soil and plant system. Plants absorb the fertilizers through the soil through which they can enter the food chain (Grant, 2018; Zhang et al., 2018). Thus, fertilization leads to water, soil and air pollution as reported by Hua et al., (2016).

One major goal of the present administration in Nigeria with respect to agricultural policy is how to make the country self-sufficient in food production. As a result of this, several efforts have been made at increasing crop production such as Rice, Maize and Cassava with appreciable results recorded. Owing to the nature of the soil in the northern Nigeria, fertilizer has been identified as the main source of soil nutrient for agricultural production (Olayide et al., 2009; Gellings and Parmenter, 2016). The use of fertilizer in this regard on soil in order to improve agricultural yield has been practiced for years and this has produced tremendous results, especially in the northern part of Nigeria (Morris et al., 2007; Savci, 2012; Sheahan and Barrett, 2017). While fertilizers and manures greatly improves agricultural yield, it is also important to consider the corresponding effects of fertilizer leaching on groundwater since other habitants also depend on it for sustenance. According to Marouane et al. (2014), fertilizer and pesticide application as part of agricultural activities has been identified as the most sensitive cause of groundwater contamination.

Most research in recent times with regard to environmental quality has been focused on water quality, because of its relevance to maintaining the human health and aquatic ecosystem, even while still prioritizing the productive yield of crops. Hence, in this study the amount and concentration of the fertilizer that should be applied on a given soil in order to minimize the undesirable effect on groundwater is given proper attention. Also in focus in this study is the effects of fertilizers leaching on the groundwater quality which indirectly affects the crops (if in excess) or humans (when consumed).

One of the most important parameters of the pollution of water is nitrate which is the basic component of fertilizer. Both the nitrate concentration of groundwater and surface water is increased as a result of agricultural activities. The most common form of dissolved nitrogen in groundwater is nitrate. Nevertheless, it can be found in form of nitrite (NO_2^-), nitrogen (N_2), nitrogen oxide (N_2O) and organic nitrogen. Nitrates from drinking water is absorbed in the intestinal tract and is excreted by the kidneys. The mechanism, as well as the salivary glands can concentrate nitrate. As a result, nitrate in the mouth is reduced to nitrite in the anaerobic environment.

Environmental factors of rainfall and water table levels will be one of the concerns in this study. Rainfall depth which has been correlated with water table depth has been observed to influence the pollutants transport within the unconfined and even confined aquifer. Thus, in this study, the fate of fertilizer compounds transport with regard to varied rainfall depth and fluctuating water table will be observed and monitored. Therefore, it will be hypothesized that seasonal variations in rainfall and water table movement would affect the groundwater contamination from fertilizer. Further hypothesis will be that the concentration of fertilizers reduces with soil depth, which means that the vulnerability of groundwater to pollution in the areas where intensive agriculture is practiced is high.

1.2 Statement of the Research Problem

The pollution of groundwater in areas of high agricultural activity has been reported and it is as a direct consequence of farming practices using large quantities of fertilizers and pesticides. The impacts of these practices on the pollution of groundwater have been reported in Nigeria over the years by various studies (Adelekan et al., 2011; Adetunji and Odetokun, 2011; Akinbile, 2012; Fatoba et al., 2017). Chukwu et al. (2004) reported nine years water borne diseases in Minna and also reported that major water borne diseases affecting Minna inhabitants are typhoid, diarrhea, cholera, amoebiasis and blue baby. It was concluded from these studies that majority of people affected by these diseases are people living in the suburb and close to areas where there are intensive farming activities which involve the use of agro-chemicals like fertilizers and pesticides.

NPK fertilizers is widely used in Nigeria to boost agricultural yield. And in most cases, farmers apply fertilizers on farms in rough estimates and in which sometimes excessive quantities may be applied to the soil. Thus increasing the amounts of heavy metals form such chemical deposits in groundwater. Of the pollutants of groundwater caused by fertilizers. Nitrate is a common contaminant and it causes health problems. The world health organisation and the United States environmental protection agency have established a maximum contaminant level for nitrate of 10mg/L as NO3 –N in drinking water. And in rural areas, that indulge in the use of large quantities of fertilizer for agriculture, this contaminant level is mostly exceeded.

1.3 Aim and objectives of the Study

This study is aimed at assessing the effects of chemical fertilizer on groundwater quality and the specific objectives are to determine:

i. the vulnerability of the groundwater to the use of fertilizer with soil depth.

ii. the optimum use of agro-chemicals suitable for crop growth and safe groundwater body.

iii. the degree of leaching of fertilizers into groundwater with soil depth.

1.4 Scope of the Study

This study investigates the leaching of fertilizer on agricultural soil to groundwater. While a number of factors such as variation in rainfall intensity, topography, soil type and type of crops cultivated also play a major role in the leaching of agro-chemicals in groundwater, this study is limited to varying the amount of fertilizer applied and determining its effect on groundwater while keeping a constant simulated rainfall.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

Application of agro chemicals such as fertilizers plays a major role in enhancing the fertility of the soil for agricultural productivity in recent times. This, therefore, means the primary purpose of applying fertilizers to the soil is mainly to improve the crop yield in order to enhance profitability of the farming enterprise. But the adverse environmental effects of these chemicals on soil and groundwater body in the case of fertilizer overdose has over shadowed the merits of this practice. In recent decades, changes from traditional agriculture practices to modern agriculture practices have led to the overuse of chemical fertilizers which, in turn, has resulted in higher groundwater contamination.

Some fertilizers, such as nitrate, play a more important role in the contamination of water and soil due to their physical and chemical characteristics, especially in agricultural lands. Therefore, what influences the mobility of these contaminants through soil to groundwater like soil, hydrogeological conditions, land use systems and climate differ from one location to another (Adeoye et al., 2017). Collin and Melloul (2003) also pointed out that this may be as a result of different soil and hydrogeological settings offering different vulnerability and different degrees of protection to the underlying aquifer.

Rainfall influence on the contaminants transport cannot be overemphasized. According to Pérez et al. (2003), in regions with high rainfall, such with average precipitation of 700 mm/year, nitrogen-based fertilizer residues left unused by plants may be leached away, contaminating groundwater. The contamination may occur several days even months after the fertilizers have been spread. The speed at which the contamination occurs, according to Pérez et al. (2003), depends on the nitrogenous compound concentration in the unsaturated zone of the soil, on input from atmosphere and on the hydrology of the aquifer. The precipitation influence on the fertilizers leaching to the groundwater body has been corroborated by Gunatilake (2016). There has always been a link between fertilizers leaching (in areas with a dryer climate) and intensive irrigation as well (Djaman et al., 2018).

Only a small fraction (about 2.5%) of earth's water is fresh and suitable for human consumption. The rest (more than 97%) is in oceans and seas. Of the less than 2.5% of fresh water approximately 13%is groundwater; an important source of drinking water for many people worldwide (Bachmat, 1994). For example, more than 50% of the world's population depends on groundwater for drinking water. For many rural and small communities, groundwater is the only source of drinking water (Canter, 1987).

Groundwater is a major source of fresh water for the global population and is used for domestic, agricultural, and industrial uses. Approximately one third of the global population depends on groundwater for drinking water (International Association of Hydrogeologists, 2020). Groundwater is a particularly important resource in arid and semi-arid regions where surface water and precipitation are limited (Li et al., 2017). Securing a safe and renewable supply of groundwater for drinking is one of the crucial drivers of sustainable development for a nation. However, urbanization, agricultural practices, industrial activities, and climate change all pose significant threats to groundwater quality. Contaminants, such as toxic metals, hydrocarbons, trace organic contaminants, pesticides, nanoparticles, micro plastics, and other emerging contaminants, are a threat to human health, ecological services, and sustainable socioeconomic development (Li, 2020; Li and Wu, 2019).

Groundwater contamination can impact human health, environmental quality, and socioeconomic development. For example, many studies have shown that high levels of fluoride, nitrate, metals, and persistent organic pollutants are a health risk for human populations (Wu et al., 2020). This is especially critical for infants and children who are more susceptible to the effects of these contaminants than adults (He et al., 2020; Wu and Sun, 2016; Karunanidhi et al., 2020; Mthembu et al., 2020; Subba Rao et al., 2020; Zhou et al., 2020). For example, “blue baby syndrome,” also known as infant methemoglobinemia, is caused by excessive nitrate concentrations in the drinking water used to make baby formulas. Human health also can be affected by the groundwater contamination through effects on the food production system. Irrigation with groundwater contaminated by heavy metals and wastewater containing persistent contaminants can result in the accumulation of toxic elements in cereals and vegetables, causing health risks to humans (Jenifer and Jha 2018; Yuan et al., 2019; Njuguna et al., 2019).

Many of the contaminants in groundwater are of geogenic origin as a result of dissolution of the natural mineral deposits within the Earth’s crust (Basu et al., 2014; Pandey et al., 2016; Subba Rao et al., 2020; He et al., 2020). However, due to rapid expansion of the global population, urbanization, industrialization, agricultural production, and the economy, we now are faced with the challenge of the negative impacts of contaminants of anthropogenic origin. The countries most affected by these global changes are those that are going through rapid economic development, with many of them located in the eastern hemisphere (Clement and Meunie, 2010; Hayashi et al., 2013; Lam et al., 2015).

Groundwater contamination is defined as the addition of undesirable substances to groundwater caused by human activities (Government of Canada, 2017). This can be caused by chemicals, road salt, bacteria, viruses, medications, fertilizers, and fuel. However, groundwater contamination differs from contamination of surface water in that it is invisible and recovery of the resource is difficult at the current level of technology (MacDonald and Kavanaugh, 1994). Contaminants in groundwater are usually colorless and odorless. In addition, the negative impacts of contaminated groundwater on human health are chronic and are very difficult to detect (Chakraborti et al., 2015). Once contaminated, remediation is challenging and costly, because groundwater is located in subsurface geological strata and residence times are long (Wang et al., 2020). The natural purification processes for contaminated groundwater can take decades or even hundreds of years, even if the source of contamination is cut off (Tatti et al., 2019).

Groundwater contamination also can negatively affect the quality of lands and forests. Contaminated groundwater can lead to soil contamination and degradation of land quality. For example, in many agricultural areas in arid regions, high groundwater salinity is one of the major factors influencing soil salinization (Wu et al., 2014). The soluble salts and other contaminants, such as toxic metals, can accumulate in the root zone, affecting vegetation growth. Groundwater contaminants also can be transported by surface water-groundwater interactions, leading to deterioration of surface water quality (Teng et al., 2018).

Sustainable economic development requires a balance between the rate of renewal of natural resources and human demand (Li et al., 2017). Freshwater is probably the most valuable of the natural resources. However, chronic groundwater contamination may reduce the availability of freshwater, breaking the balance between water supply and demand and leading to socioeconomic crises and even wars. Water shortages induced by contamination may become a factor causing conflicts among citizens in the future (Schillinger et al., 2020), possibly delaying the socioeconomic development of a nation. Groundwater contamination is not only an environmental issue but also a social issue, demanding collaboration between both natural scientists and social scientists.

Toxic metals and metalloids are a risk factor for the health of both human populations and for the natural environment. Chemical elements widely detected in groundwater include metals, such as zinc (Zn), lead (Pb), mercury (Hg), chromium (Cr), and cadmium (Cd), and metalloids, such as selenium (Se) and arsenic (As). Exposures at high concentrations can lead to severe poisoning, although some of these elements are essential micronutrients at lower doses (Hashim et al., 2011). For example, exposure to hexavalent chromium (Cr^{6+}) can increase the risk of cancer (He, and Li, 2020). Arsenic is ranked as a Group 1 human carcinogen by the US Environmental Protection Agency (EPA) and the International Agency for Research on Cancer (IARC), and As^{3+} can react with sulfhydryl (–SH) groups of proteins and enzymes to upset cellular functions and eventually cause cell death (Abbas et al., 2018). Toxic metals in the environment are persistent and subject to moderate bioaccumulation when they enter the food chain (He and Li 2020; Hashim et al., 2011).

Organic contaminants have been widely detected in drinking water, and many of these compounds are regarded as human carcinogens or endocrine disrupting chemicals. In groundwater, more than 200 organic contaminants have been detected, and this number is still increasing (Lesser et al., 2018; Jurado et al., 2012; Lapworth et al., 2012; Sorensen et al., 2015).

2.2 Nitrate as Concerning Groundwater Contamination

Nitrate is one of the most prevalent groundwater contaminants in the world (Nolan and Stoner, 2000; Rosenstock et al., 2014), and concentrations are increasing (Spalding and Exner, 1993). The National Academy of Engineering (2008) identified nitrogen management as one of the grand challenges facing the United States. Numerous studies document that agricultural activities are a source of elevated nitrate in groundwater: Almasri, and Kaluarachchi, 2004; Hudak, 2002; Harter et al., 2002; Lindsey et al.,1998; Dzurella et al., 2012, Sánchez-Pérez et al., 2003; Yin et al., 2007; Erickson and Norton, 1990; Zebarth et al., 1998; Carey and Harrison, 2014; EPA, 2013; Burkholder et al., 2007; Sajil Kumar et al., 2013; Ju et al., 2006; Nolan and Stoner, 2000; Rosenstock et al., 2014; and Olson et al., 2009; concluded that in agricultural areas within the United States that 19% of the shallow groundwater wells do not meet the groundwater standard of 10 mg N/L. They also concluded that groundwater nitrate concentrations are higher in agricultural areas than in urban areas.

Nitrogen contaminants, such as nitrate, nitrite, and ammonia nitrogen, are prevalent inorganic contaminants. Nitrate is predominantly from anthropogenic sources, including agriculture (that is fertilizers, manure) and domestic wastewater (Hansen et al. 2017; He and Wu, 2019; He et al. 2019; Karunanidhi et al. 2019; Li et al. 2019; Serio et al. 2018; Zhang et al. 2018). Groundwater nitrate contamination has been widely reported from regions all over the world. Other common inorganic contaminants found in groundwater include anions and oxyanions, such as F^-, SO_4^{2-}, and Cl^-, and major cations, such as Ca^{2+} and Mg^{2+}. Total dissolved solids (TDS), which refers to the total amount of inorganic and organic ligands in water, also may be elevated in groundwater. These contaminants are

usually of natural origin, but human activities also can elevate levels in groundwater (Adimalla and Wu, 2019).

When nitrates and other pollutants associated with animal manures and commercial fertilizers are not managed properly, they can affect plant and animal life (including humans) negatively. Some of these impacts include algae blooms causing oxygen depletion in both surface water and groundwater (O'Boyle et al. 2016; Breitburg et al., 2018), pathogens and nitrates in drinking water (Hassan and Mostfa 2017; Resto et al., 2018) and the emission of odors and gases into the air (Giungato et al. 2016; Cheng et al., 2019). Nutrients from manure and fertilizers enter aquifers, lakes and streams through infiltration, runoff and soil erosion. High levels of nitrates can be toxic to livestock and humans. Nitrates are not adsorbed to soil materials, so they may leach to groundwater (Pratiwi et al., 2016; Ito, 2018).

In some instances, stored or land-applied manures or nitrogen fertilizers have caused high concentrations of nitrates in water (Viguria et al., 2015; Taneja et al., 2019). Because nitrates freely leach down through the soil profile, nitrogen that is not used for crop or plant growth can reach the groundwater easily. Nitrate in itself is not toxic to animals, but at higher levels, it causes a disease called nitrate poisoning. High levels of nitrates in drinking water are known to cause methemoglobinemia (blue-baby syndrome) in human infants and other warm-blooded animals (Tatti et al., 2019). In humans and livestock, nitrates interfere with oxygen uptake in the circulatory system. Generally, when soil-test nitrogen (N) and phosphorus (P) increase, greater amounts of plant-available N and P move with water. Runoff water from fields with high soil-test N and P may contain a high level of these dissolved nutrients, increasing the risk of contaminating streams, wetlands and lakes. In addition, erosion carries fine particles of soil that are enriched with nutrients. Eroded soil particles with attached nutrients will accumulate as sediment in water resources and serve as a source of available nutrients during long periods of time.

Varieties of mathematical and numerical models has been used to assess the vulnerability of shallow aquifer by estimating time of arrival of pollutants percolating through the vadose zone from the ground surface to the water table. However, the estimation does not always represent reality. In their research, Jafari et al. (2016) investigated a new risk assessment method to better predict the vulnerable areas and incorporate risk probability into the forecast. They presented a different approach to evaluate the risk of occurrence of contamination in an unconfined aquifer. Risk was evaluated using a combination of three different factors: vulnerability index, probability of occurrence, and contamination index. They concluded that the areas with high contamination risk are areas with either high vulnerability index and/or high probability of occurrence. Areas with low vulnerability index which in other methods are considered safe and protected against contamination, with high probability of contamination potential are still areas of concern and should be treated as high risk area.

Hermanson et al. (2000) provided the following general principles and recommendations drawn from their comprehensive review:

1. The estimation of agronomic rate for a crop must factor in all sources of nitrogen available during the growing season. This includes mineralization, residual inorganic nitrogen, and contribution from irrigation water. Agronomic rate is defined as the recommended rate of nitrogen addition to the soil that is needed to produce an expected yield, while minimizing adverse environmental effects.

2. In waste management scenarios, agronomic rate and the application rate may be different. When the application rate is in excess of the agronomic rate, close attention must be given to the environmental consequences of this practice.

3. All nitrogen applied to the soil, that is not volatilized, will eventually convert to nitrate. The total transformation to nitrate may take a few weeks to a few years, depending on the nature of the organic waste.

4. Nitrate moves readily with water in the soil profile and can reach groundwater if not taken up by the crops, denitrified, or volatilized. Other forms of nitrogen are less mobile.

5. Soil nitrogen that moves below the root zone will eventually leach to groundwater as nitrate. Steps should be taken to minimize movement of nitrogen below the root zone during the growing and non-growing seasons.

6. Denitrification may reduce nitrate loading to groundwater under some conditions, though it is of little importance in well-drained soils.

7. Nitrogen applied at the time and in the amounts needed by the crop will minimize the buildup of soil nitrogen.

9. Wastes applied substantially before or after maximum crop demand may result in the buildup of inorganic soil nitrogen that will subsequently be susceptible to nitrate leaching.

10. Use of winter cover crops can minimize movement of nitrogen deeper into the soil profile by utilizing the nitrogen in the root zone, storing it in the plant tissue, and ultimately returning it to the soil surface after the cover crop dies. Cover crops temporarily store nitrogen removed from the root zone.

11. Winter cover crops are not a reason to over-apply nitrogen. If excess nitrogen is applied in one growing season, it must be offset by decreased nitrogen application the following season to avoid residual nitrogen buildup and subsequent nitrogen leaching.

12. Poor irrigation management will prevent efficient nitrogen management and recovery.

13. The nitrogen composition of the manure should be determined before application because it will affect the timing of nitrogen availability and the susceptibility to nitrate leaching.

14. Maximizing nitrogen removal by crops (by attempting to maximize crop production and increase nitrogen uptake) will generally increase the risk of nitrate accumulation in the soil.

15. Organic wastes applied during the non-growing season will partially or totally convert to nitrate before the next growing season. The fraction mineralized will depend on the manure composition, the soil temperature and moisture conditions. The depth that nitrates will travel in the soil before the next growing season will depend on the soil hydraulic properties and the volume of recharge (precipitation and irrigation). Nitrate leached beyond the root depth of the crops to be grown during the following season will be susceptible for transport to groundwater.

16. Steps should be taken to minimize movement of nitrogen below the root zone during the growing and non-growing season.

17. Applying organic wastes during the non-growing season has an inherent risk in terms of leaching nitrogen to groundwater.

18. The use of storage facilities to minimize waste applications during the non-growing season is a safe alternative.

2.3 Phosphorous in Groundwater

Phosphorus is an essential element for life, it is highly reactive and combines to form a variety of compounds. Phosphorus may occur as orthophosphate ion (PO4 3-) in water and is also present in all life forms as an essential component of cellular material. Naturally in the ecosystems, phosphorus is derived from the erosion of rocks and is conserved for plant growth as it is returned to the soil through animal waste and the decomposition of plant and animal tissue. In agricultural systems, some phosphorus is removed with harvest, since phosphorus is concentrated in the seeds and fruit. Phosphorus is added to soil through chemical fertilizers, manure, and composted materials.

Phosphorus gets retained in soil by adsorption. Hence Soils have a limited capacity to store phosphorus, once the capacity of soil to adsorb phosphorus is exceeded, the excess will dissolve and move more freely with water either directly to a stream or downward to an aquifer. Surface-water runoff from rainstorms or excess irrigation is the primary way that phosphorus or soil containing phosphorus is transported to streams in most watersheds. There is a growing awareness that long-term over-application of manure and chemical fertilizer contributes to phosphorus movement into the groundwater system, resulting in a significant groundwater source of phosphorus to streams and lakes, as well as potential contamination of the groundwater resources.

Applied fertilizer leaching and surface-level phosphorus runoff can contribute to excess algal growth in downstream water bodies, a condition known as eutrophication. Excessive amounts of algae in eutrophic water bodies can result in significant daily changes in the amount of dissolved oxygen in water as a result of photosynthetic activity but then decrease at night. Low levels of dissolved oxygen can cause stress or kill sensitive species that inhabit the water. This study examined phosphorous concentrations and movement in soils and groundwater in five agricultural environments in the United States, climate, irrigation usage, and cropping systems to assess potential phosphorus movement in the soil and groundwater under common agricultural conditions. The study design included This type of information could potentially be used to formulate best management practices to limit the transport of phosphorus from the agricultural fields assessment of a variety of agricultural practices, especially cropping patterns and irrigation, so that the factors that contribute to phosphorus movement to groundwater, or sequestration of the phosphorus to soil could be compared and examined.

Phosphorus may be immobilized by adsorption and mineralization, limiting its mobility inside or below the root region. Inorganic phosphorus is found in water mainly as orthophosphate, which has a negative charge. While orthophosphate is water soluble, it can bind to soil particles and adsorb. Clays and phosphate minerals are the two types of minerals that are most responsible for orthophosphate adsorption in soils. Furthermore, the formation of calcium phosphate minerals in soils rich in calcium carbonate will restrict phosphorus movement. The total surface area of the oxides or clays in a soil limits the amount of orthophosphate that can be adsorbed. Any additional orthophosphate will cause the sorption sites on the mineral surfaces to become saturated with orthophosphate or other ions. Iron oxides' ability to adsorb and hold orthophosphate is influenced by the presence of dissolved oxygen in the surrounding water as well as a pH below neutral (less than 7). Soils and aquifers with low dissolved oxygen or pH values greater than around 7 are more likely to become saturated with orthophosphate than oxic or acidic soils and aquifers.

Iron oxides can dissolve and release adsorbed phosphorus back into the water in the absence of oxygen, causing dissolved phosphorus concentrations to rise. Iron oxides do not naturally dissolve in aquifers with low levels of dissolved oxygen because this process is dependent on the presence of specific bacteria.

2.4 Potassium in Groundwater

Potassium is a vital nutrient for humans, but it is rarely, if ever, present in drinking water at levels that are harmful to healthy people. It can be found in a wide range of environments, including all natural waters. It can also be found in drinking water as a result of potassium permanganate being used as an oxidant in water treatment. In certain countries, potassium chloride is used instead of or in combination with sodium chloride in ion exchange for household water softening, allowing potassium ions to exchange with calcium and magnesium ions. It has been proposed that potassium salts may be used to supplement or partially replace sodium salts in desalinated water conditioning.

Concerns about total dietary sodium intake, especially in developed countries where high salt intake from processed foods is a concern, have prompted the shift to potassium. On the other hand, some people are concerned that their diets are deficient in potassium. This is not a problem for the general population; however, elevated potassium intake may have serious health consequences in people with kidney disease or other conditions including cardiac disease, coronary artery disease, hypertension, diabetes, adrenal insufficiency, pre-existing hyperkalaemia, and older people with dwindling physiological reserves.

2.5 Use of Lysimeter

Use of lysimeter to study migration of contaminants to groundwater has also been recognized for many years because it has been of major importance in the development of understanding of soil water and contaminants dynamics in the subsurface. Earliest lysimeter consisted of a container filled with soil repacked to a similar bulk density of that in the fields. Ehler and Goss (2003) and Goss et al., (2010) developed a non-weighing drainage lysimeters and tension lysimeter by placing a wick in contact with the soil body to carry

water down into the collecting vessel. Goss and Ehlers, (2009) developed a hybrid weighing lysimeter which allows the contaminant load entering unconfined shallow groundwater to be identified. Karthikeyan et al. (2008) studied the migration of fecal matter through soil with a drainage non-weighing lysimeters. The results from all these studies and more show fast movement of these bacteria as a result of very permeable nature of the vadose zone soil. The concentrations of these chemicals seem to be reducing as they move through the soil mass.

Several cases of water borne diseases have been documented in Minna over the years. Chukwu et al. (2004) reported nine years water borne diseases in Minna and also reported that major water borne diseases affecting Minna inhabitants are typhoid, diarrhea, cholera, amoebiasis and blue baby. It was concluded form his study that majority of people affected by these diseases are people living in the suburb and close to area where there are intensive farming activities like dairy, slaughters house and poultry activities. Some groundwater sampling campaign in North central Nigeria and Minna (Jimoh et al., 2003; Salami et al., 2008; Isikwue et al., 2011) have reported presence of nitrates, phosphates and biological parameters especially inside the poultry farms as a result of indiscriminate dumping of poultry manure. However, a mechanism guiding the transport of the pollutants through the vadose zone into the groundwater has not been adequately studied. There is therefore a need to ascertain behaviour of poultry manure contaminants through the soil profile to be able to predict and explain danger posed to groundwater aquifers by continuous and excessive application of poultry manure to agricultural lands.

Erickson (1994) investigated the effects of dairy lagoons on groundwater quality in Washington State. This researcher found leakage at three of the four lagoons investigated, and two had sufficient leakage to impact local groundwater quality. He also noted that the proximity of the water table to the lagoon liner was an important factor that affected the ammonium load to the subsurface. This study also found elevated levels of chloride, total dissolved solids (TDS), bacteria, total organic carbon, chemical oxygen demanding substances, and ammonium in groundwater near leaking lagoons. The predominance of ammonium over nitrate was attributed to the close proximity of the lagoons to the water table and the saturated soils beneath the lagoon, which created anaerobic conditions. The maximum concentration of ammonium was 180mg N/L, with a typical range of 30 to 60mg N/L. Some level of nitrification occurred with nitrate concentrations in groundwater noted at over 90mg N/L at one site, over 80mg N/L at another, and concentrations that exceeded the 10mg N/L groundwater standard at the third site.

Garland and Erickson (1994) conducted a groundwater quality evaluation in the area in and around a dairy lagoon in Wacom County, Washington. Sampling began before the lagoon was used and continued for three years after. These researchers concluded that leakage from the lagoon adversely impacted groundwater quality (causing exceedances of the drinking water standard) in the immediate vicinity of the lagoon. Ham, (2002) noted that discharge from manure lagoons occurs and these losses can affect groundwater quality.

In Washington State, nitrate has contaminated public and private drinking water supplies. Groundwater is considered contaminated when it does not meet (exceeds) a drinking water standard. The drinking water standard set by Environmental Protection Agency (EPA) for nitrate is 10 mg N/L. Locations where elevated nitrate levels in groundwater have been documented. Nitrate groundwater contamination is a persistent widespread issue in the Lower Yakima Valley, the Lower Columbia Basin, and the Sumas-Blaine area in Wacom County.

It is difficult to assess the direct impacts of Animal Feeding Operations (AFO) on groundwater quality in Washington State, since, there are only a few groundwater studies that assess impacts of AFOs in Washington State. EPA (2013) recently conducted a groundwater investigation in the Lower Yakima Valley which linked Concentrated Animal Feeding Operation (CAFO) discharges to groundwater contamination. In non-point source pollution, Agricultural activities contributes approximately 75% of nitrogen pollution in the total pollution in the United States of America. And Agriculture is a primary source of river and groundwater pollution in rural areas in the United Kingdom Groundwater is an important source of water supply for Municipalities, agriculture and industry. Therefore the capability to predict the behaviour of chemical contaminates in flowing groundwater is of vital importance for a). The reliable assessment of hazardous or risks arising from groundwater contamination problems, and b) the design of efficient and effective techniques to mitigate them. There are several studies reported in this filed. Reliable and quantitative prediction of contaminant movement can be made only if we understand the processes controlling the transport of contaminants. These include a) advection, b) hydrodynamic dispersion and c) physical, chemical and biological reactions that affect their soluble concentrations in groundwater.

The assessment of agricultural impacts on water quality is now being redirected to include both groundwater and surface water. Agricultural Non-Point Source (NPS) pollution has several unique characteristics. Agricultural production generally takes place in an uncontrolled environment involving vast land areas with pollutant losses affected by the complex interrelationships of meteorology, management and cropping practices, geology, topography, and soils. NPS pollution is a diffuse source phenomena affecting water on

filed, watershed, or regional scale. Because NPS pollution is derived from unpredictable climatic events, it must be treated as stochastic problem with consideration for long-term risks.

Possible groundwater pollutants from agricultural production activities include nitrogen, pesticides and their inherent compounds. Surface water pollutants include phosphorous and sediment. If agricultural waste management is considered- involving the application of animal manures to cropland additional pollutant include bacteria, other microorganisms, and biodegradable, oxygen-demanding organic substances (such as fecal matter). Pollution control requires a diverse collection of chemical, managerial, and structural (such as. terraces, diversions, and other soil conservation structure) practices. The economic implications (cost benefit ratio) of each management practice, or combinations thereof should be considered in assessing any NPS pollution alternative.

Because of the complexity of NPS pollution, the development of abatement techniques is not a simple process. Only two methods for assessing the effectiveness of NPS management techniques currently exist: (1) actual field testing of alternatives, or (2) computer modelling of various management scenarios. Field testing is limited to the number of locations and scenarios that can be feasibly examined and requires several years of observations to collect valid data that reflect climate variability. Long-term rainfall records and rainfall generation techniques can be used to examine the interactions between meteorology and management alternatives.

The use of Geographic Information System (GIS) in assessing the spatial distribution of pollutant fluxes reaching an urban unconfined aquifer system in Birmingham, UK. Urban groundwater recharge and pollution is a complex and poorly understood process. No suitable method is available for assessing the amount of recharge and pollutant fluxes

reaching in urban aquifer sustainability, a desktop GIS (Arc View GIS and Arc View Spatial Analyst extension)-based runoff-recharge–pollutant flux model has been developed to estimate the potential recharge and pollutant fluxes to an urban unconfined aquifer system. The authors explained how an integrated approach (involving analysis of various thematic maps and other attribute information of a UK urban area using the above desktop GIS-based recharge pollutant flux model could help in assessing the amount of groundwater recharge and pollutant fluxes (currently a few chosen pollutant species such as nitrate, chloride, and Benzene, Toluene, Ethylbenzene, and Xylene (BTEX) compounds) reaching to the groundwater of the Birmingham area.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of Study Area

The study area is Gidan Kwano Inland Valley located between Latitude 9^{o} 5000' and 9^{o} 5625' N and Longitude 6^{o} 373' and 6^{o} 4375' E. The valley is located at the western end of Minna, a North-Western town in Niger State, Nigeria within the permanent site of Federal University of Technology, Minna. The catchment area of the basin 30.79 km^{2}. The soil type on the study area was in a textural class of gravelly sand up to the depth of 80 - 90cm. The area is characterized with low and erratic rainfall of between 1000 to 1200mm as total annual rainfall with peaks in July and August.

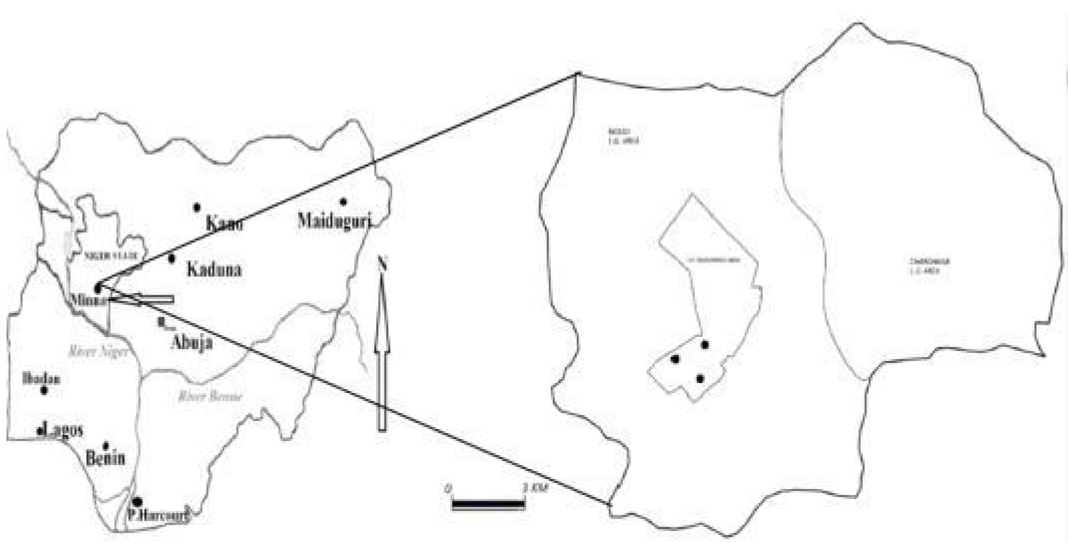

Figure 3.1: Map of Nigeria showing the proposed study area (Source: Adeoye et al., 2017)

3.2 Materials

1. A lysimeter, a bucket-like device for undisturbed soil samples collection and to monitor agrochemical movement. They are termed monolith lysimeters to indicate that the cores are captured intact with undisturbed profiles of soil. The lysimeters is open at both ends.

2. Valves attached to the lysimeters from where the water samples is collected

3. NPK 20:10:10 Fertilizers as agro-chemicals

4. 150 litres storage tank

5. 1 Tap stopper, connected to an 8cm shower rose and calibrated to simulate rainfall at a constant discharge of 0.093L/s

6. Sterilized plastic bottle being fitted tightly to serve as water samples collectors during the experimental runs

7. Colorimeter (Hach DR 4000) to determine the chemical parameter present in the samples collected

8. Desktop computer and printer for data entry and printing works

9. Permeability meter for hydraulic permeability determination

10. Set of sieves for sieve analysis

3.3 Experimental Method and Data Collection

To study potential groundwater contamination from fertilizer leaching, the best technique available is the use of lysimeters. The lysimeters, which is a steel cylinder, open at both ends, was constructed using a 3mm thick steel plate. The lysimeters has a diameter of 30cm with a length of 100 cm and three lysimeters of these same dimensions was fabricated for this study (Figure 3.2). Three points within the study area were selected for this study. Upon selecting the three agricultural zones, the lysimeters were pushed into the soil in order to collect the soil samples undisturbed. The pushing of lysimeters were done in a way to keep intact the soil profile with little disturbance to the study area.

Before the cylinders were pushed into the soil, the upper 30cm of soil were removed since that part of the soil is disturbed by tillage. Once the cylinders gets completely filled, the top and bottom were covered with plywood boards to prevent the soil from falling out during extraction, modification and movement to the laboratory. The lysimeters were then extracted and turned upside down. The lysimeters were transported to the laboratory and attached to the stand with perforated base through which water could be drained. The bottom of each lysimeters were closed except for a small opening through which the drainage water was made to channel with a gentle slope to a container placed beneath it. Each lysimeters was left for 2 weeks to allow for stabilization of soil mass inside the lysimeters before the experimental analysis (application of fertilizers). The lysimeters is ensured to be water-tight in such a way that water applied as simulated rainfall (Figure 3.2) will not drain out in the process of experimental analysis. From the study areas where the undisturbed samples are being collected using lysimeters, soil samples were collected at 30cm and 60cm soil depths using polythene bags and taken to laboratory for the

determination of hydraulic conductivity, soil moisture content and particle size distribution Each of the polythene bags used was labeled for identification and the properties of the soil were determined. For each experimental analysis, the NPK (20:10:10) fertilizers was applied at different quantities to the soil samples in two lysimeters and the third lysemeter is used as control. The NPK was being applied at different quantities in each of the lysemeters (from 87.37g to 100g). The rainfall intensity was simulated and kept at a constant discharge in the three lysemeters. The rainfall intensity conversion rate of 1 litre/m^2 = 1 mm as regard FAO (1986).

At the end of each rainfall simulation (NPK fertilizers applied first in an appropriate quantities), space of one week was allowed before water samples were collected using sterilized cans at the soil depths of 30 cm and 60 cm. Water samples collection continued on weekly basis for 3 months before the rainfall simulation was repeated.. The water sampling for this category was continued on weekly basis for another three months. This makes the entire sampling procedure a total period of nine (9) months as stated earlier. The collected samples were refrigerated in the laboratory for further analysis. Analysis were done in the laboratory for the determination of the following parameters: pH, EC, TDS, CO_3^{2-}, HCO_3^-, Ca^{2+}, Mg^{2+}, Cl^-, DO, COD, Na^+, K^+, NO_3^-, PO_4^{3}.

Results obtained were subjected to analysis of variance to determine if the water samples properties changed with date of collection and to ascertain if the depth, from which the samples were taken have any effect on water properties. Interaction between time of fertilizers application on the undisturbed soil core and the depth at which the water samples were collected and determined. The mean values obtained were subjected to Duncan Multiple Range Test (DMRT).

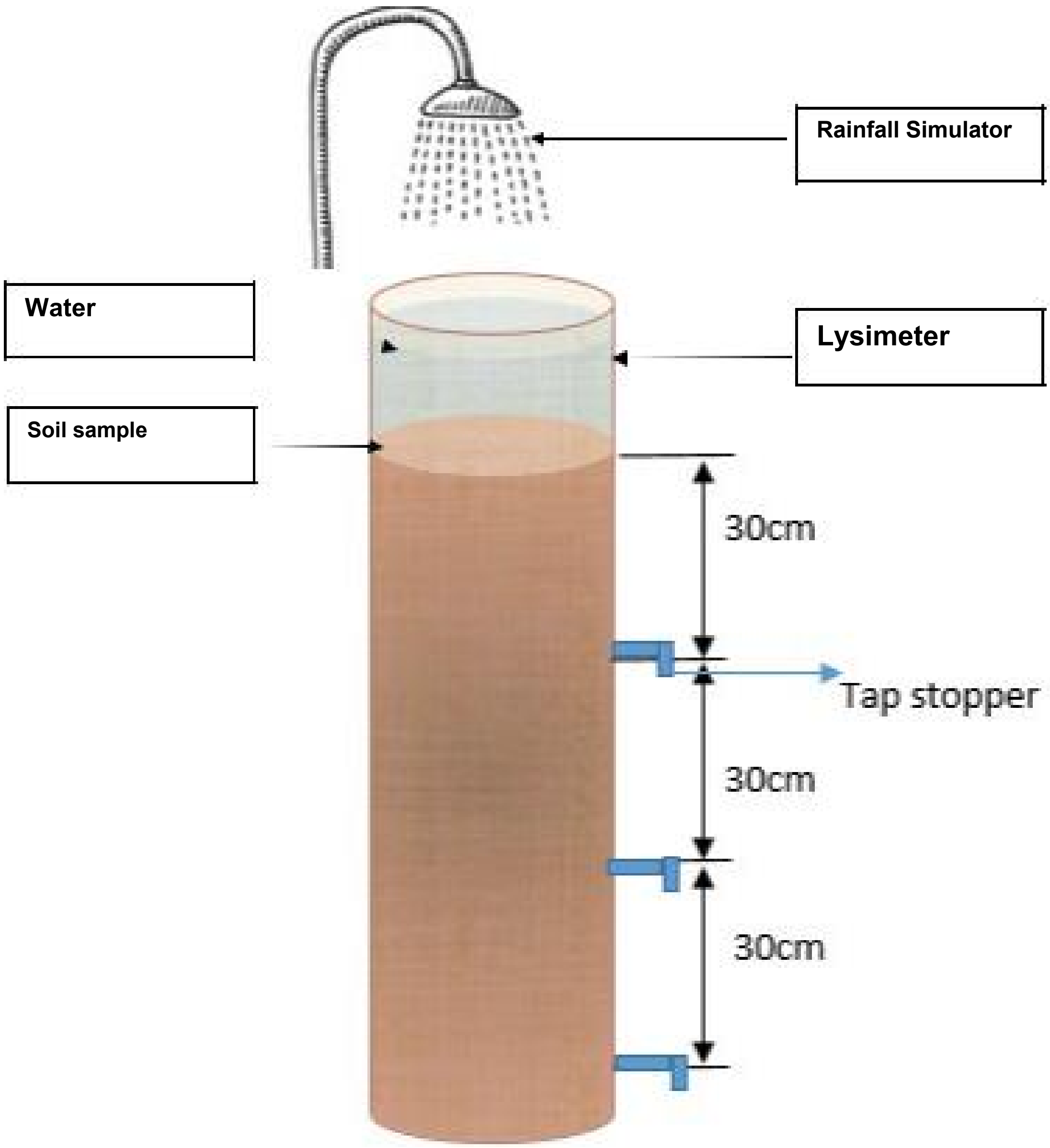

Figure 3.2: Experimental setup

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Results

The results of the physico-chemical parameter of the water samples for the experiment 1 where 87.37g of NPK fertilizers were applied on the first soil column and samples tested at intervals of weeks 1 to 4, is as presented in Tables 4.1 and 4.2. In Table 4.1, a mean values were obtained by calculating the average of the minimum and maximum values of A1 –A3 at 30cm and A4-A6 at 60cm depths for each week. Also, results of the analysis for Experiment 2 in which 100g of NPK fertilizer was applied, is presented in Table 4.3 to 4.4. More details of raw data obtained from laboratory analysis are presented in tables in appendix.

Hence,

Table 4.1: Results of physico-chemical analysis of groundwater for experiment 1 (on application of 87.37g of NPK fertilizer at 30 cm depth)

	pH	EC (µ /cm)	TA mg/l	TH mg/l	Ca mg/l	Mg mg/l	Cl mg/l	COD mg/l	HCO3 mg/l	Fe mg/l	PO4 mg/l	NO3 mg/l
WEEK 1	7.625	807	40.5	103	19.34	12.37	207.5	2268.5	18.29	6.94	6.905	5.175
WEEK 2	7.5	860	45.5	107	33.37	23.75	212.5	2406	20.42	5.72	5.57	2.66
WEEK 3	7.24	895	51	119.5	33.22	27.95	218	2565	22.325	5.15	5.295	3.025
WEEK 4		832	54	120.2	31.09	28.22	215.5	2578	22.43	4.98	5.012	3.192

Table 4.2: Results of physico-chemical analysis of groundwater for experiment 1 (on application of 87.37g of NPK fertilizer at 60 cm depth)

	pH	EC (µ /cm)	TA mg/l	TH mg/l	Ca mg/l	Mg mg/l	Cl mg/l	COD mg/l	HCO3 mg/l	Fe mg/l	PO4 mg/l	NO3 mg/l
WEEK 1	7.065	503.5	25	158	35.32	19.615	14.705	29.14	10.305	1.245	3.49	1.43
WEEK 2	7.135	524.5	27	111	35.32	21.785	14.705	77	10.665	1.11	3.14	0.15
WEEK 3	7.05	543.5	32.5	117	19.16	22.35	19.4	210	11.785	1.155	3.895	2.27
WEEK 4		520.2	34.12	119	18.34	24.32	21.12	220	13.26	1.09	3.46	2.49

Table 4.3: Results of physico-chemical analysis of groundwater for experiment 1 (on application of 100 g of NPK fertilizer at 30 cm depth)

	pH	EC (µ /cm)	TA mg/l	TH mg/l	Ca mg/l	Mg mg/l	Cl mg/l	COD mg/l	HCO3 mg/l	Fe mg/l	PO4 mg/l	NO3 mg/l
WEEK 1	6.81	4140.00	58.33	154.67	34.20	19.18	207.00	3566.67	19.41	6.27	6.89	5.48
WEEK 2	6.92	4214.33	61.33	163.67	39.57	29.20	217.00	3885.00	24.29	5.42	5.78	4.15
WEEK 3	7.13	4360	68	182.07	48.5	35.2	254	4212	32.23	4.89	5.67	3.62
WEEK 4		4355	69.5	186.4	46.5	36.4	250	4227	33.12	4.34	5.32	3.78

Table 4.4: Results of physico-chemical analysis of groundwater for experiment 1 (on application of 100 g of NPK fertilizer at 60 cm depth)

60 cm	pH	EC (µ /cm)	TA mg/l	TH mg/l	Ca mg/l	Mg mg/l	Cl mg/l	COD mg/l	HCO3 mg/l	Fe mg/l	PO4 mg/l	NO3 mg/l
WEEK 1	6.81	571.33	39.67	97.33	19.62	13.91	153.21	1275.00	12.54	3.08	3.11	1.74
WEEK 2	6.62	633.33	41.33	105.33	24.37	22.47	132.67	1946.67	11.44	1.37	3.04	2.34
WEEK 3	6.76	732.33	42.67	110.00	32.30	28.63	153.21	2185.33	12.66	3.08	2.45	2.23
WEEK 4	6.69	723.12	45.53	114.21	29.12	30.14	154.02	2201.12	12.98	2.12	2.12	2.98

4.2 Migration of Chemical Parameters

Chemical parameters values obtained varied both with depths and the time (weeks) after application of NPK fertilizers on the lysimeter. As shown in Figure 4.1, higher total alkalinity was observed at 30 cm depth compared to what was obtainable at 60 cm soil depth. This could be as a result of low soil permeability of the soil mass which means that fertilizer particles leaching in the soil layer is slow as a result of hydraulic conductivity of the soil. After the introduction of NPK fertilizer particles on the lysimeter and rainfall simulation, a week was observed before the water samples collection at both depths. Based on the available results, chemical parameters of the water samples collected witnessed sharp increase between depths and 60cm. Highest values of total alkalinity (TA), soil calcium, Phosphate, and nitrates values were recorded at depths 30cm one week after the fertilizer particles were introduce. Similarly, concentration of NPK fertilizer was increased from 87.37 g to 100 g and it was observed that highest TA, calcium, magnesium, Chlorine, nitrates and phosphates values were obtained with the application of 100 g of fertilizers as compared to 87.37 g.

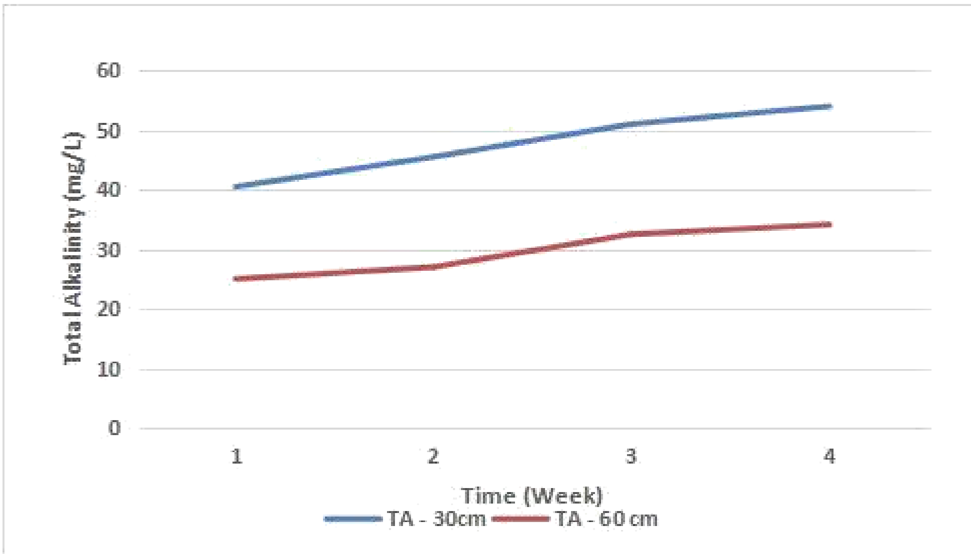

Figure 4.1: Variation of Total alkalinity concentration of water samples varied with soil depth at 87.37g

From Tables 4.1 and 4.2, effects of depths and fertilizer concentrations on total alkalinity concentration was established respectively as it shows that the deeper the soil, the lower the concentration of TA. And also the more the applied fertilizers, the more the effects on groundwater as presented when compared to Table 4.3 and 4.4 and as can be seen on Figure 4.2. Furthermore, it is observed that total alkalinity shows an increase in concentration with time.

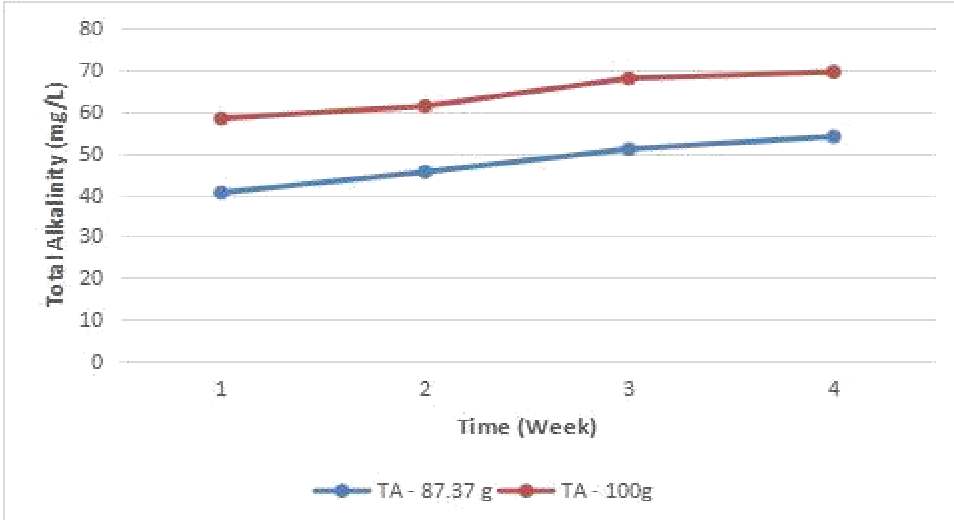

Figure 4.2: Variation of Total alkalinity concentration of water samples varied with NPK levels in water

As presented on Tables 4.1 and 4.2, effects of depths and fertilizer concentrations on calcium concentration was established respectively. From Figure 4.3, it is seen that at 30cm depth, calcium concentration increased from week one to week two and declines to week four. But the concentrations declined more at 60c depth which shows that the deeper the soil, the lower the concentration of calcium. And also the more the applied fertilizers, the more the effects on groundwater as presented on Figure 4.4.

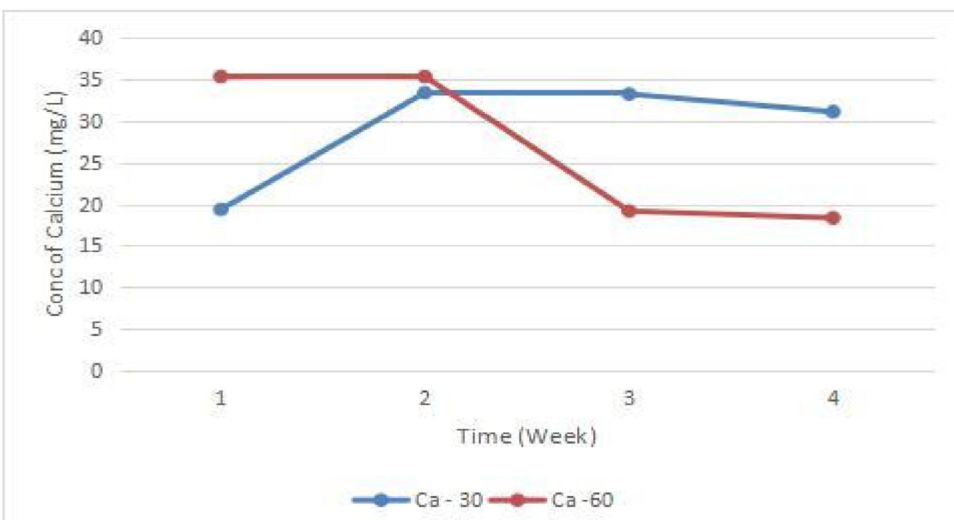

Figure 4.3: Variation of Calcium concentration of water samples varied with soil depth at 87.37g

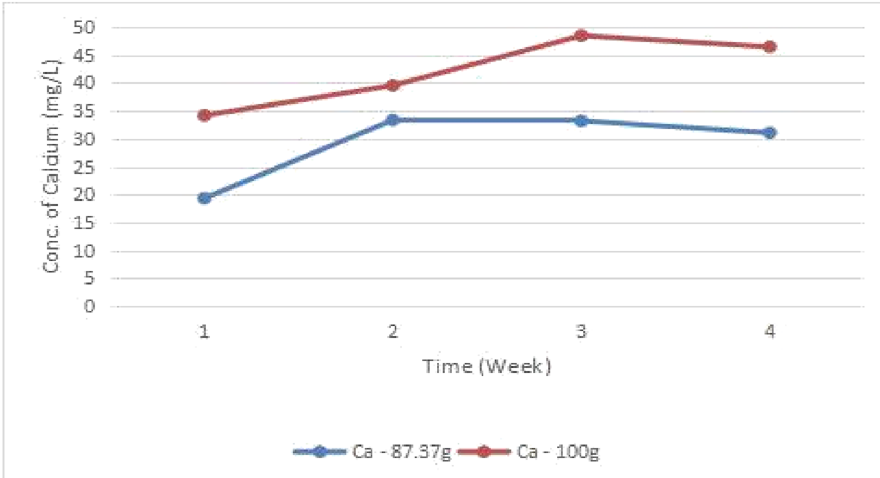

Figure 4.4: Variation of Calcium concentration of water samples varied with NPK levels in water

From tabulated results, and on graphical representation of Figure 4.5 and 4.6, effects of depths and fertilizer concentrations on magnesium concentration was established respectively as it shows that the deeper the soil depth, the lower the concentration of Magnesium. And also the more the applied fertilizers, the more the effects on groundwater as presented Figure 4.6. It is also observed that concentrations inclines with time.

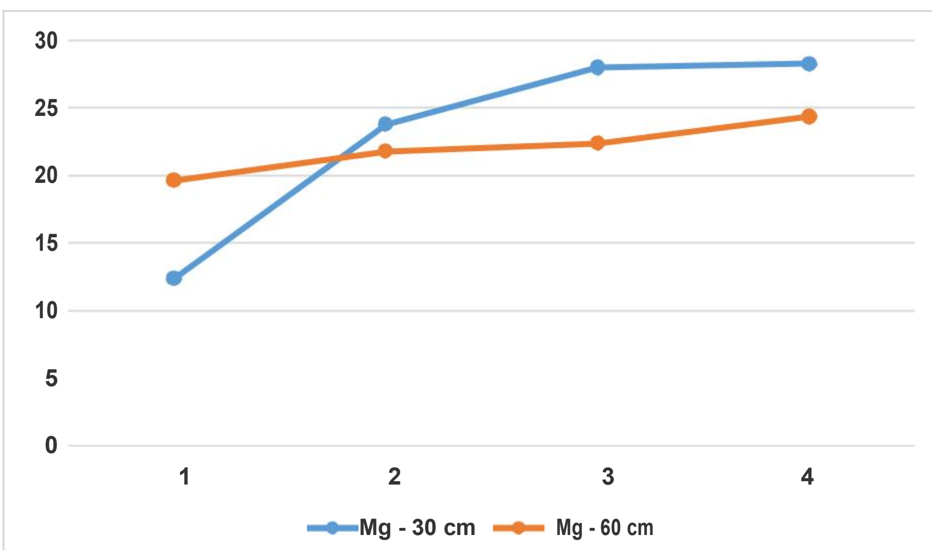

Figure 4.5: Variation of Magnesium concentration of water samples varied with soil depth at 87.37g

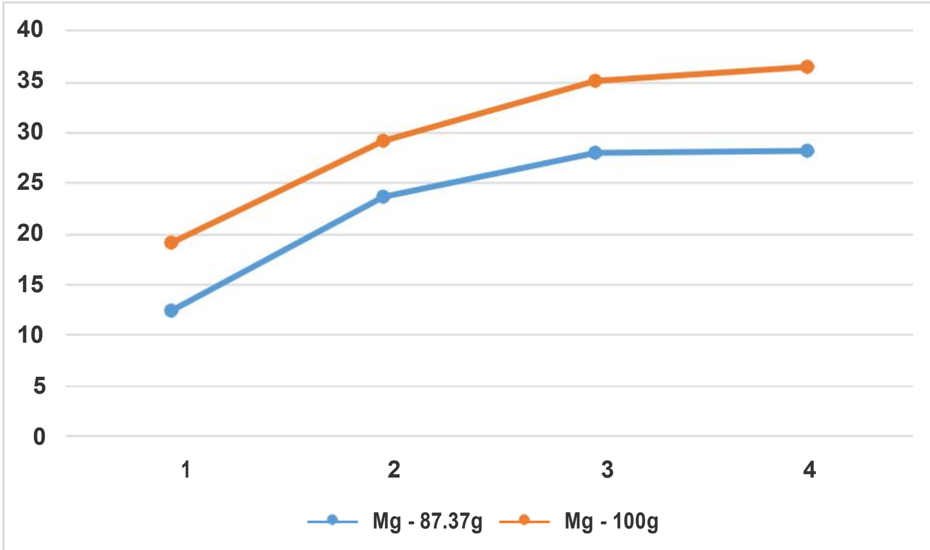

Figure 4.6: Variation of Magnesium concentration of water samples varied with NPK levels in water

Similar to other elements, concentration of chlorine decreased with soil depth and increased with increased NPK fertilizer application as can be seen from Tables and Figure 4.7 and 4.8. More clearly on Figure 4.8, it is seen that chlorine concentration varied directly proportional with time especially on application of 100g of NPK fertilizer.

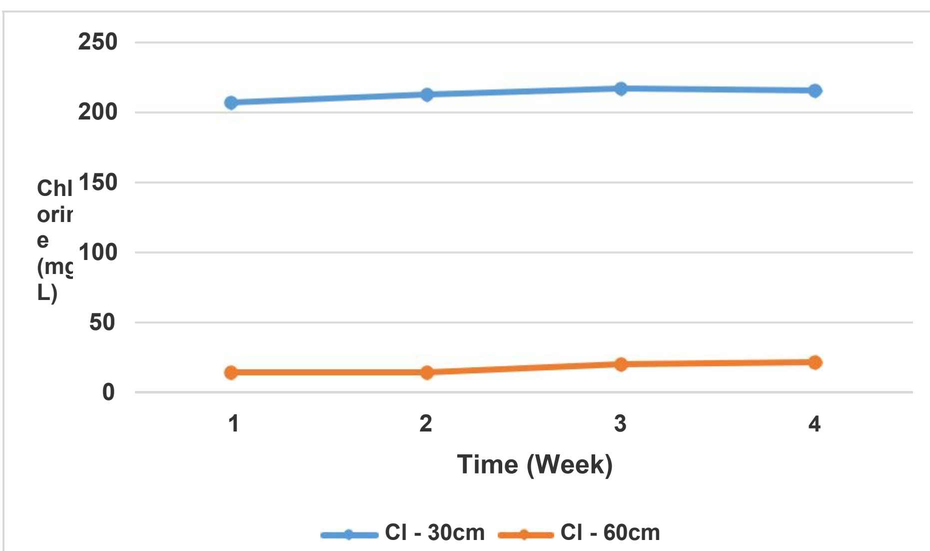

Figure 4.7: Variation of Chlorine concentration of water samples varied with soil depth at 87.37g

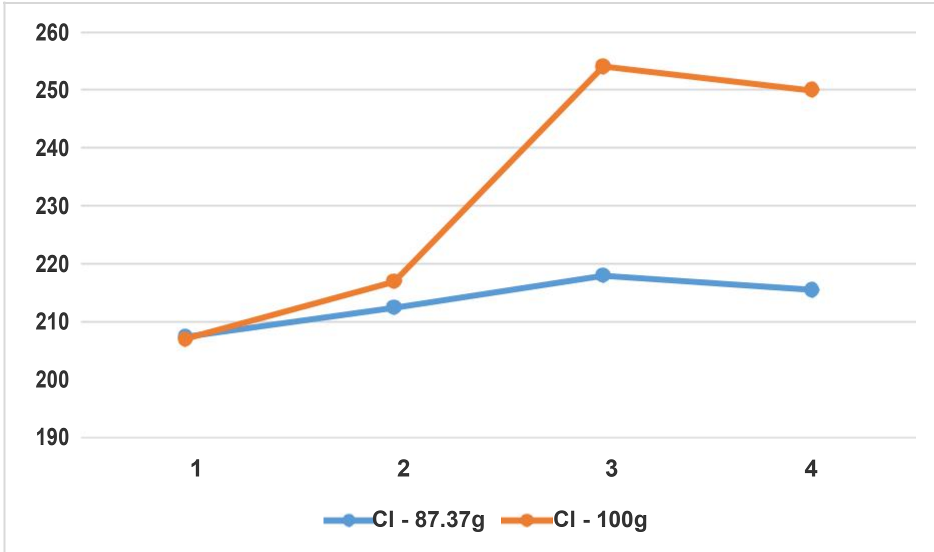

Figure 4.8: Variation of Chlorine concentration of water samples varied with NPK levels in water

From Figure 4.9 and 4.10, a similar trend is observed as concentrations of HCO_3 decreased considerably from 30cm to 60cm depth and concentrations increased on application of 100g NPK fertilizer relative to the application of 83.73g. and the concentrations varies directly proportionally with time.

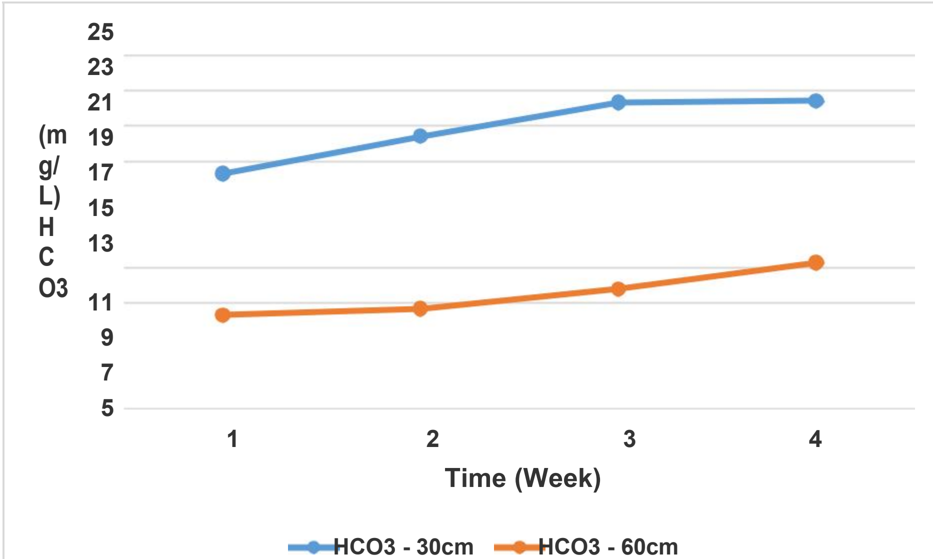

Figure 4.9: Variation of HCO_3 concentration of water samples varied with soil depth at 87.37g

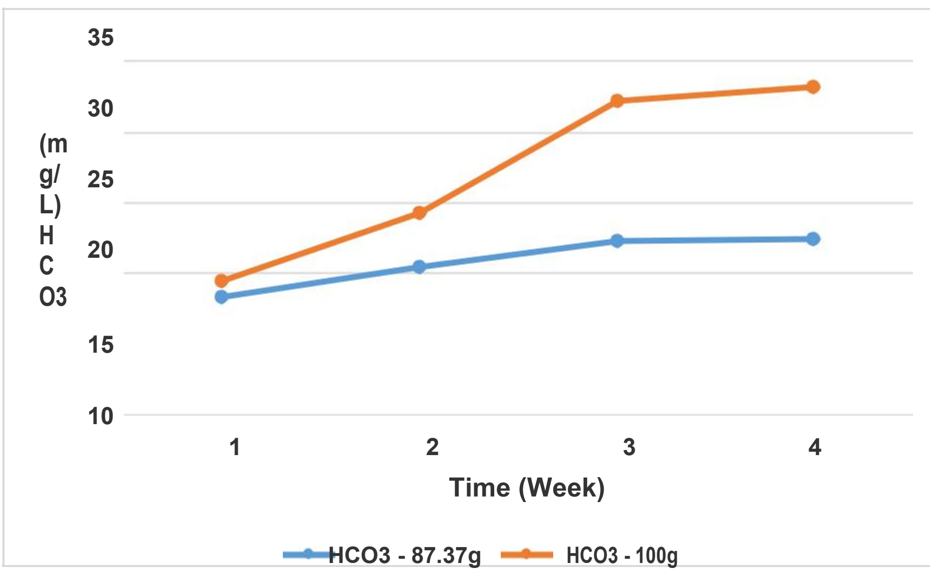

Figure 4.10: Variation of HCO_3 concentration of water samples varied with NPK levels in water

From Tables and Figure 4.11 and 4.12, it is seen that the concentration of PO4 decreased considerably with time and depth but increased with an increase in the quantity of fertilizer application.

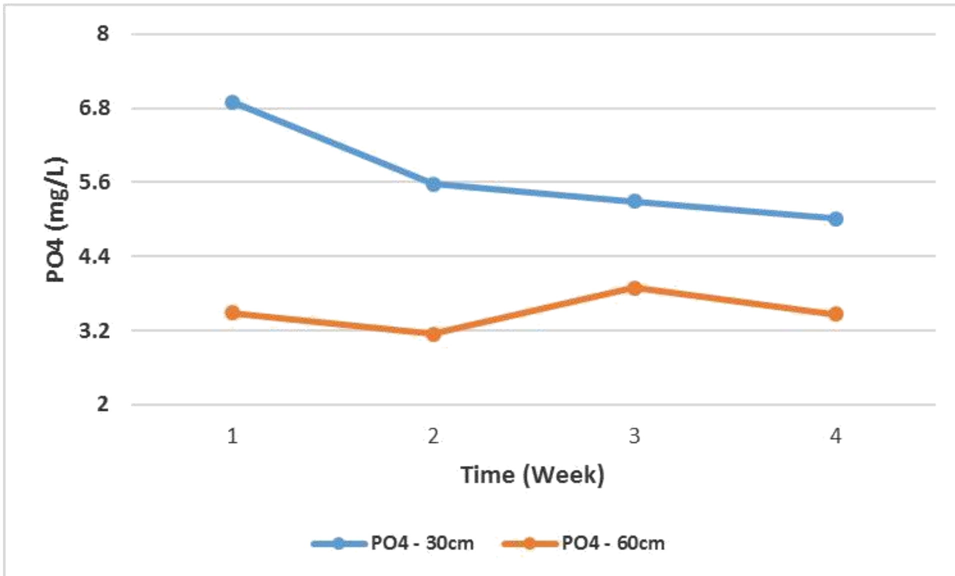

Figure 4.11: Variation of PO_4 concentration of water samples varied with soil depth at 87.37g

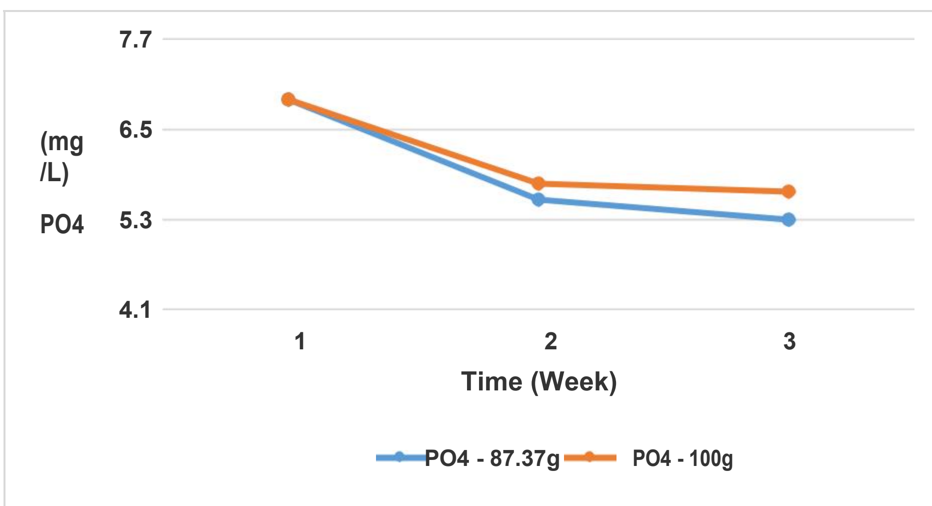

Figure 4.12: Variation of PO_4 concentration of water samples varied with NPK levels in water

As presented on Tables 4.1 and 4.2, effects of depths and fertilizer concentrations on Nitrate concentration was established respectively. From Figure 4.13, it is seen that at 30cm depth, nitrate concentration decreased from week one to week two and inclines to week

four, that means it concentration of nitrates increases with time. But the concentrations declined more at 60cm depth which shows that the deeper the soil, the lower the concentration of nitrates. And also the more the applied fertilizers, the more the effects on groundwater as presented on Figure 4.14.

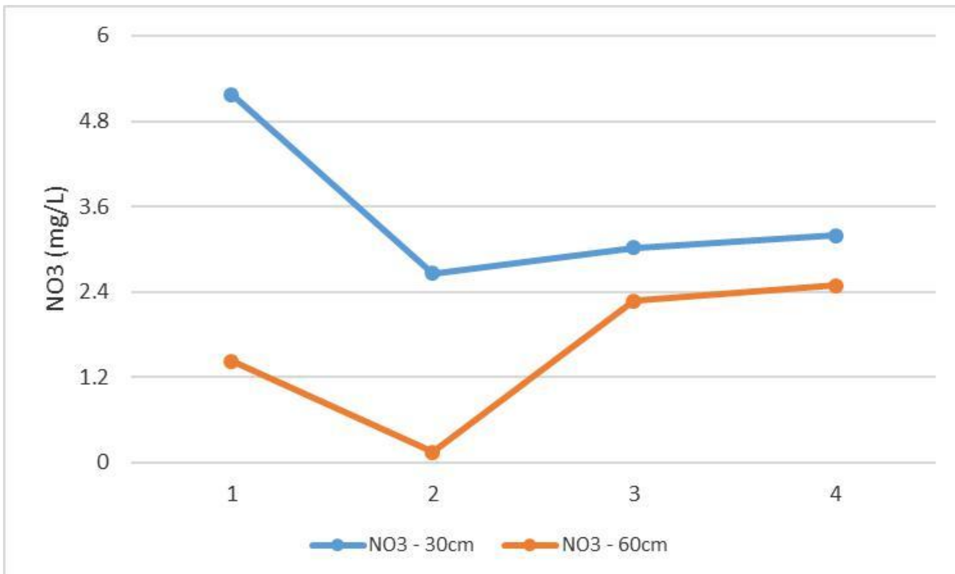

Figure 4.13: Variation of NO_3 concentration of water samples varied with soil depth at 87.37g

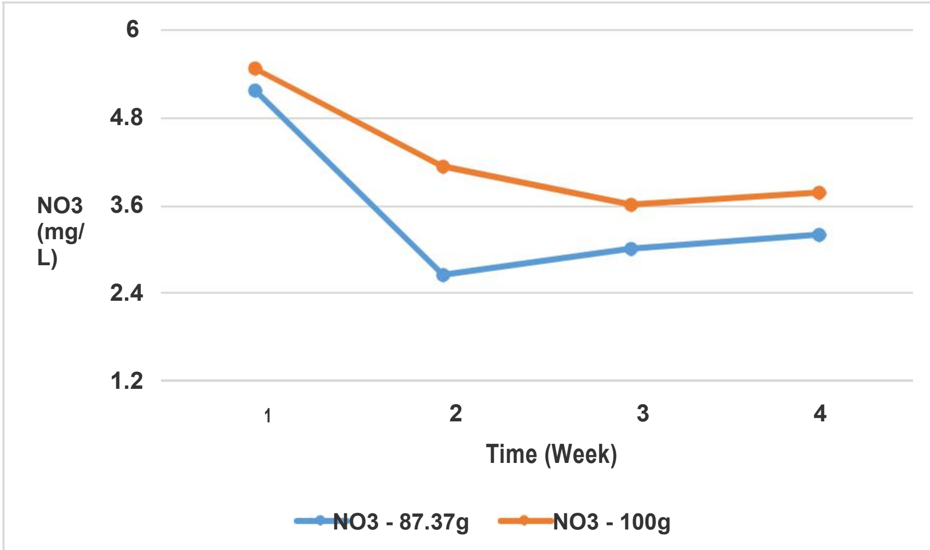

Figure 4.14: Variation of NO_3 concentration of water samples varied with NPK levels in water

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The Effect of Chemical Fertilizers on Groundwater Quality in an Unconfined Aquifer has been studied. This study has showed that the soil on the experimental plots have ability to take in fertilizer particles as they migrate deep down into the soil mass. Nitrates and phosphates generally decline in concentrations as they move with soil depths. They were able to leach up to 60 cm of soil depth of the undisturbed soil column. These observations were attributed to high porosity of the soil and high hydraulic conductivity which ranged from 0.489 – 0.81m/day according to hydraulic parameters analysis carried out on the soil of the area.

The results obtained in this study can be used as baseline to know the precise application of fertilizers needed for optimum crop productivity with little negative effects on human consumption of groundwater bodies. The results of this study can also help in modelling the fertilizers particles movement in the soil columns. This information from this study can also be used as input parameters into modern software and models for predicting contaminant fate, transport and persistence in unconfined aquifer.

5.2 Recommendations

The effect of chemical fertilizer on ground water quality in an unconfined aquifer is of great importance. Hence, further research on this topic is recommended where more soil samples will be used and also to an increased depth so as to understand better the variation of physic-chemical changes with soil depth. In further studies, it is recommended that a

variation of simulated rainfall (Q) be introduced, more variation to quantity of fertilizer application, and possibly introducing certain plants in the experimental process.

5.3 Contribution to Knowledge

The effects of fertilizers on groundwater quality has been studied. This study has therefore given the optimum amount of fertilizers needed to be applied on cultivated land that will be safe for both crops and groundwater. In other words, with these quantities of fertilizers applied, there would be appreciable crop yield and safe groundwater for human consumption.

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APPENDICES

Appendix A: Results of physico-chemical analysis of groundwater for experiment 1 (on application of 83.73g of NPK fertilizer week 1)

SAMPLE ID	pH	EC (µ /cm)	TA mg/l	TH mg/l	Ca mg/l	Mg mg/l	Cl mg/l	COD mg/l	HCO3 mg/l	Fe mg/l	PO4 mg/l	NO3 mg/l
A1 30cm	7.6	1001	45	112	28.59	16.83	185.22	2460	20.61	7.5	6.35	5.22
A2 30cm	7.64	752	40	86	26.07	24.08	194	2384	18.04	6.38	6.6	4.85
A3 30cm	7.65	613	36	120	40.37	29.76	162.68	2077	15.97	6.75	6.47	5.5
A4 60cm	7.05	535	24	110	25.23	6.97	15.86	26.88	9.79	1.11	3.65	1.35
A5 60cm	7.08	472	24	102	27.75	7.05	13.55	29.25	9.79	1.38	3.4	1.51
A6 60cm	7.06	506	26	98	16.82	7.01	15.6	31.4	10.82	1.29	3.75	1.48

Appendix B: Results of physico-chemical analysis of groundwater for experiment 1 (on application of 83.73g of NPK fertilizer week 2)

SAMPLE ID	pH	EC (µ /cm)	TA mg/l	TH mg/l	Ca mg/l	Mg mg/l	Cl mg/l	COD mg/l	HCO3 mg/l	Fe mg/l	PO4 mg/l	NO3 mg/l
A1 30cm	7.8	1050	52	119	28.59	25.2	221	2500	22.5	6.21	5.82	3.38
A2 30cm	7.2	830	42	95	26.07	25,1	189	2450	20.32	5.67	5.32	3.5
A3 30cm	7.21	670	39	115	40.37	22,3	204	2312	18.34	5.23	5.54	1.94
A4 60cm	7.09	550	27	118	25.23	20.3	15.86	120	11.32	1.09	3.24	0.15
A5 60cm	7.21	499	26	110	27.75	15.4	13.55	74	10.23	1.02	3.04	0.1
A6 60cm	7.06	510	28	104	16.82	15.76	15.6	34	10.01	1..2	3.23	0.15

Appendix C: Results of physico-chemical analysis of groundwater for experiment 1 (on application of 83.73g of NPK fertilizer week 3)

SAMPLE ID	pH	EC (µ /cm)	TA mg/l	TH mg/l	Ca mg/l	Mg mg/l	Cl mg/l	COD mg/l	HCO3 mg/l	Fe mg/l	PO4 mg/l	NO3 mg/l
A1 30cm	7.5	1110	59	122	28.59	30.3	234	2650	23.43	5.32	5.47	3.01
A2 30cm	7.2	843	48	118	26.07	29.8	202	2558	21.22	5.11	5.43	3.07
A3 30cm	6.98	680	43	117	40.37	25.6	205	2480	21.34	4.98	5.12	2.98
A4 60cm	7.08	576	34	124	25.23	23.2	22.1	342	12.32	1.11	4.67	2.56
A5 60cm	7.02	511	31	113	27.75	23.1	23.2	120	12.11	1.22	3.24	2,21
A6 60cm	7.06	523	32	110	16.82	21.5	15.6	78	11.25	1.09	3.12	1.98

Appendix D: Results of physico-chemical analysis of groundwater for experiment 2 (on application of 83.73g of NPK fertilizer week 1)

SAMPLE ID	pH	EC (µ /cm)	TA mg/l	TH mg/l	Ca mg/l	Mg mg/l	Cl mg/l	COD mg/l	HCO3 mg/l	Fe mg/l	PO4 mg/l	NO3 mg/l
B1 30cm	6.87	4100	50	132	42.05	18.3	221	3700	28.35	6.25	6.78	5.78
B2 30cm	6.77	3960	60	168	31.95	23.47	196	3600	20.1	6.3	6.87	5.89
B3 30cm	6.78	4360	65	164	28.59	15.76	204	3400	9.79	6.27	7.03	4.78
B4 60cm	6.83	549	45	100	16.82	17.08	196	1350	11.85	3.5	4.67	1.78
B5 60cm	6.78	706	44	94	21.86	7.66	140.14	1200	12.88	1.75	2.31	1.67
B6 60cm	6.66	459	30	98	20.18	16.98	123.48	1275	12.88	4	2.34	1.77

Appendix E: Results of physico-chemical analysis of groundwater for experiment 2 (on application of 83.73g of NPK fertilizer week 2)

SAMPLE ID	pH	EC (µ /cm)	TA mg/l	TH mg/l	Ca mg/l	Mg mg/l	Cl mg/l	COD mg/l	HCO3 mg/l	Fe mg/l	PO4 mg/l	NO3 mg/l
B1 30cm	6.97	4122	54	143	45.2	28.2	243	4200	30.12	5.69	6.22	4.23
B2 30cm	6.82	4111	63	176	38.3	30.1	210	3805	22.43	5.45	5.89	3.99
B3 30cm	6.98	4410	67	172	35.2	29.3	198	3650	20.32	5.12	5.23	4.23
B4 60cm	6.83	620	48	110	25.3	24.1	152	2300	13.42	1.91	3.65	2.34
B5 60cm	6.78	770	45	106	24.6	18.2	134	1820	8.12	1.12	3.58	2.12
B6 60cm	6.25	510	31	100	23.2	25.1	112	1720	12.78	1.09	1.89	2.56

Appendix F: Results of physico-chemical analysis of groundwater for experiment 2 (on application of 83.73g of NPK fertilizer week 3)

SAMPLE ID	pH	EC (µ /cm)	TA mg/l	TH mg/l	Ca mg/l	Mg mg/l	Cl mg/l	COD mg/l	HCO3 mg/l	Fe mg/l	PO4 mg/l	NO3 mg/l
B1 30cm	7.01	4189	57	149	48.5	33.1	254	4212	32.23	4.89	5.67	3.55
B2 30cm	7.13	4144	64	182	42.2	35.2	196	3712	25.65	4.24	5.43	3.5
B3 30cm	6.98	4360	68	179	40.1	34.2	162.68	3400	27.44	4.67	4.98	3.62
B4 60cm	6.83	701	48	115	35.3	31.2	196	2543	13.45	3.5	2.49	2.22
B5 60cm	6.78	818	46	112	32.2	29.4	140.14	2208	12.67	1.75	2.56	2.13
B6 60cm	6.66	678	34	103	29.4	25.3	123.48	1805	11.87	4	2.31	2.34

Appendix G: Results on Sieve analysis of the soils within the study area Sieve analysis at 30cm

Sieve size	weight of seive can(g)	weight of sieve +sample A	weight of sieved sample A(g)	weight of sieve +sample B (g)	weight of sieved sample B(g)	weight of sieve + sample C(g)	weight of sieved sample C(g)
5	474.8	475.5	0.7	475.6	0.8	474.8	0
3.35	468.1	468.5	0.4	468.4	0.3	468.6	0.5
2.36	433.8	435.5	1.7	435.1	1.3	435.9	2.1
2	417.7	419.3	1.6	419.1	1.4	419.6	1.9
1.18	385	396.7	11.7	395.5	10.5	398.7	13.7
0.85	351.9	360.9	9	361.4	9.5	363.4	11.5
0.6	467.9	482.3	14.4	481.3	13.4	482.2	14.3
0.425	435.1	449.9	14.8	451.2	16.1	450.5	15.4
0.3	313	337.9	24.9	330.6	17.6	330.3	17.3
0.15	420.5	453.9	33.4	459.7	39.2	454.2	33.7
0.075	330.2	341.8	11.6	346.9	16.7	343.6	13.4
Pan	297.4	310.7	13.3	309.1	11.7	310	12.6
			137.5		138.5		136.4

Appendix H: Sieve analysis at 60cm

seive size	weight of seive can(g)	weight of sieve+sample A	weight of seived sample A	weight of sieve +sample B	weight of seived sample B	weight of sieve + sample C	weight of seived sample C
5	474.8	475	0.2	480	5.2	474.9	0.1
3.35	468.2	468.7	0.5	469.3	1.1	469.9	1.7
2.36	433.8	435.6	1.8	435.7	1.9	436.3	2.5
2	417.2	419.6	2.4	419.4	2.2	419.4	2.2
1.18	385	398.3	13.3	394.4	9.4	395.6	10.6
0.85	351.9	362.3	10.4	362.6	10.7	361.9	10
0.6	468.1	480.9	12.8	483.4	15.3	483	14.9
0.42	435.2	448.1	12.9	455.5	20.3	454.1	18.9
0.3	313	327.5	14.5	340.7	27.7	336.6	23.6
0.15	420.9	449.7	28.8	467.4	46.5	462	41.1
0.07	336.8	342.2	5.4	347.7	10.9	346.4	9.6
pan	297.4	299.1	1.7	303.4	6	300.3	2.9
			104.7		157.2		138.1

Appendix I: Moisture content at 30cm

	SAMPLE A			SAMPLE B			SAMPLE C		
TRIAL	1	2	3	1	2	3	1	2	3
CAN NO.	ABC1	ABC10	ABC5	ABC7	ABC2	ABC9	H2	ABC 6	ABC 8
Weight of can	24.5	24.6	24.5	24.8	25.2	24.9	38.8	24.4	24.5
Weight of can + wet soil	54.8	61.3	55.7	67.8	72.3	67.1	87.3	70.8	62.8
Weight of can + dry soil	50.6	56.1	51.3	61.5	65.4	60.9	80.5	63.8	57.2
Moisture content	4.2	5.2	4.4	6.3	6.9	6.2	6.8	7	5.6

Appendix J: Moisture content at 60cm

	SAMPLE A			SAMPLE B			SAMPLE C		
TRIAL	1	2	3	1	2	3	1	2	3
CAN NO.	ABC1	ABC10	ABC5	ABC7	ABC2	ABC9	H2	ABC 6	ABC 8
Weight of can	24.5	25	25.1	24.4	24.5	24.5	24.3	24.7	24.9
Weight of can + wet soil	53.3	48.5	47.8	46.9	50.1	43.6	46.2	54.9	46
Weight of can + dry soil	51.3	45.8	46.8	44.5	44.6	41.3	43.5	50.8	42.6
Moisture content	2	2.7	1	2.4	5.5	2.3	2.7	4.1	3.4