IMPACT ASSESSMENT OF WASTEWATER IRRIGATION ON CROP GROWTH: SPINACH (Spinacea oleracea) AS A CASE STUDY

BY

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DECLARATION

I hereby declare that this project work is a record of a research work that was undertaken and written by me. It has not been presented before for any degree or diploma or certificate at any university or institution. Information derived from personal communications, published and unpublished work were duly referenced in the text.

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CERTIFICATION

This project entitled "Impact Assessment of Wastewater Irrigation on Crop Growth: Spinach (Spinacea oleracea) as Case Study" by Oladele, Waliu Kayode, meets the regulations governing the award of the degree of Bachelor of Engineering (B.ENG.) of the Federal University of Technology, Minna, and it is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

I dedicate this project work to my parent Alhaji Oladele, yusuf Jogbodo and Alhaja Oladele, simbiat Adunni and my lovely wife Mrs. Oladele, suleat Abiola for standing by me before and during the program. I always appreciate their trust in me and I want to use this medium to tell that I would never let them down.

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ABSTRACT

Non availability of fresh water due to rapid increase in population has attracted the attention of farmers to the use of wastewater for irrigation. Physical and chemical analyses of the wastewater were carried out to determine their effects on Spinach growth. Two plots were used, one irrigated with wastewater and the other irrigated with fresh water which served as the control plot. Vegetables from the plot irrigated with wastewater had higher length of stems and broader leaves and these may be related to high Nitrogen content of the wastewater. The average weight and yield of the vegetables from wastewater irrigated plots and the control plot were 1.20kg ; 0.36kg and 3.7071 kg/m^2 ; 1.1121 kg/m^2 respectively. The results from wastewater analyses showed that the pH value 7.56, potassium content 15.41 mg/l and bicarbonate content 166 mg/l were within the FAO recommended limit however; calcium and Nitrogen content 40.48 mg/l, 182.45 mg/l respectively were above the recommended range. This wastewater can be used to optimize spinach production though should be treated to avoid irrigation threats.

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CHAPTER ONE

INTRODUCTION

1.1 IRRIGATION

A reliable and suitable irrigation water supply can result in vast improvements in agricultural production and assure the economic vitality of the region. Many civilizations have been dependent on irrigated agriculture to provide the basis of their society and enhance the security of their people. Some have estimated that as little as 15-20 percent of the worldwide total cultivated area is irrigated (Smith et al, 2005). Judging from irrigated and non-irrigated yields in some areas, this relatively small fraction of agriculture may be contributing as much as 30-40 percent of gross agricultural output. Effective agronomic practices are essential components of irrigated systems. Management of the soil fertility, cropping selection and rotation, and pest control may make as much incremental difference in yield as the irrigation water itself. Irrigation implies drainage, soil reclamation, and erosion control. When any of these factors are ignored through either a lack of understanding or planning, agricultural productivity will decline.

Irrigated agriculture faces a number of difficult roblems in the future. One of the major concerns is the generally poor efficiency with which water resources have been used for irrigation. A relatively safe estimate is that 40percent or more of the water diverted for irrigation is wasted at the level through either deep percolation or surface runoff (Salihu, 2008). These losses may not be lost when one views water use in the regional context, since return flows become part of the usable resource elsewhere. However, these losses often represent foregone opportunities for water because they delay the arrival of water at downstream diversions and because they almost universally produce poorer quality water. One of the more evident problems in the future is the growth of alternative demands for water such as urban and industrial needs. These uses place a higher value on water resources and therefore tend to focus attention on wasteful practices. Irrigation science in the future will undoubtedly face the problem of maximizing efficiency.

The Future Irrigation – Practice and Technology program is focused on providing the leadership and capacity to capture, develop and promote new irrigation practices, technologies and management systems to ensure the social, economic and environmental sustainability of the urban, pre-urban and rural irrigation sectors. Services provided by program staff will include the identification and development of tools and techniques to enable the industry to double the value of irrigated output while reducing the volume of water required to be diverted for both urban and rural irrigation.

The Future Irrigation program has addressed the needs of irrigators and those who advise, support and supply irrigation dependent enterprises. This has been achieved through research projects which work across commodities, regions and States. New information has been developed on the plant response to new irrigation methods, urban residential and sports groundwater use and availability and use of software tools. New tools have been developed to valuate dam evaporation reduction options, improve grower management of irrigation systems nd provide estimates of evapotranspiration across Australia on a daily basis. New equipment as been developed for measuring on-farm dam storage volumes and losses, assessing the performance of surface irrigation systems and measuring deep drainage losses. New information on innovative irrigation management practices has been developed. Within the Improving the Precision of Irrigation project, the use of partial rootzone drying and regulated deficit irrigation practices have been assessed in crops from pears to cotton. The Open Hydroponics project has examined the intensive, innovative horticultural management practice which uses almost continuous irrigation with nutrient enriched water. The irrigation and nutrition management principles used by open hydroponics systems can be efficient but the level of efficiency is directly linked to the implementation of good management. A preliminary ecological risk assessment identified several major risks to sensitive catchments from open hydroponics.

The Improving the Precision of Irrigation project is developing the tools and frameworks for assessing and determining the importance of crop variation across the paddock. Based on this, the potential of adapting irrigation systems to deliver variable rate irrigation applications can be assessed within both biophysical and profitability frameworks. There is surprisingly little information on the use of water for irrigation in our own backyards and parks. Over summer, the Urban Irrigation project measured water use across fifty homes in Sydney to determine that irrigation of our gardens and lawns accounted for 34% of total household water use (November – March). The Software for Best Use of Water project has identified nineteen software packages developed for improving management of water on-farm. By compiling and publishing information on each of the software packages, the project has highlighted the strengths and weaknesses of software currently available. This will guide decisions regarding further development and use (Smith et al, 2005).

1.2 WASTEWATER

Wastewater irrigation is a common terminal treatment practice for liquid municipal, industrial and agricultural waste. Management guidelines established for freshwater irrigation are often not relevant for wastewater irrigation. In rural and peri - urban areas of developing countries, the use of sewage and wastewater for irrigation is a common practice (BAE, 2002). Wastewater is often the only source of water for irrigation in these areas. Even in areas where other water Sources exist, small farmers often prefers wastewater because its high nutrient content reduces or even eliminates the need for expensive chemical fertilizers (Barker, 2002).

The use of domestic wastewater for crop production has been practiced for several centuries in one form or another. Prior to the 1940s, most wastewater use occurred on "sewage farms" or areas specifically designated for such use. One of the oldest in the world is the Werribee Farm which serves the City of Melbourne, Australia. This large well-managed farm was established in 1897 and is still in operation today, irrigating some 10 000 ha with wastewater. The impetus for these "sewage farms" was to minimize or prevent pollution in rivers and conserve water and nutrients to improve agriculture (FAO, 2004). Few of these "sewage farms" still exist today; most were ill-conceived, inadequately funded and poorly regulated, and were eventually abandoned because of public health concerns. In the mid 1940s, domestic wastewater use again gained increased attention, especially in arid and semi-arid areas that suffer from insufficient overall water supplies. Although the same early motivations for wastewater use remained, the newer areas using wastewater were focused on ensuring they minimized or prevented potential public health problems. The principal concern was use of wastewater on crops normally eaten raw. The change in focus was driven by a better understanding of public health problems and the desire to improve public health standards.

The need to improve public health protection prompted a number of state health departments in the United States to establish guidelines and regulations to control the public health aspects of wastewater use in agriculture. These initial guidelines provided a rational basis for continuing wastewater use by agriculture while meeting strict public health criteria. One important criterion was to restrict the use of partially treated sewage to crops that are generally cooked before being consumed and allow only water that has gone through advanced wastewater treatment and microbial disinfection to be applied to crops normally eaten raw.

Many nations adopted the very strict microbial standards for wastewater use that were developed in California (USA) and elsewhere. In reality these microbial standards were almost unattainable in most wastewater treatment systems, therefore many poorer or developing countries abandoned plans for wastewater use (FAO, 2004). The primary reason was the realization that producing effluent with a microbial quality sufficient for unrestricted irrigation required costly sophisticated treatment technology. Some of these countries shifted their focus in wastewater use to unrestricted areas of use coupled with crop restrictions. Most, however, did not have a strong institutional structure to control cropping. The result has been little improvement in public health conditions associated with wastewater use. Untreated or partially treated wastewater continues to be used directly for unrestricted irrigation or is discharged to surface water channels where unintended use by agriculture occurs when water is appropriated for irrigation use.

There are agronomic and economic benefits of wastewater use in agriculture. Irrigation with wastewater can increase the available water supply or release better quality supplies for alternative uses. In addition to these direct economic benefits that conserve natural resources, the fertilizer value of many wastewaters is important. (FAO, 2004) estimated that typical wastewater effluent from domestic sources could supply all of the nitrogen and much of the phosphorus and potassium that are normally required for agricultural crop production. In addition, micronutrients and organic matter also provide additional benefits. There are many successful wastewater use schemes throughout the world where nutrient recycling is a major benefit to the project (FAO, 2004). Rarely, however, is a scheme laid out or planned on the basis of nutrient recycling. The primary constraint to any wastewater use project is public health.

Wastewater, especially domestic wastewater, contains pathogens which can cause disease spread when not managed properly. The primary objective of any wastewater use project must therefore be to minimize or eliminate potential health risks. In most developing countries direct wastewater use projects are normally centered near large metropolitan areas. These schemes often only use a small percentage of the wastewater generated. The result is that indirect use of wastewater prevails in most developing countries. Indirect use occurs when treated, partially treated or untreated wastewater is discharged to reservoirs, rivers and canals that supply irrigation water to agriculture. Indirect use poses the same health risks as planned wastewater use projects, but may have a greater potential for health problems because the water user is unaware of the wastewater being present. Indirect use is likely to expand rapidly in the future as urban population growth outstrips the financial resources to build adequate treatment works. Where ndirect use occurs, the primary objective must also be to ensure that it is in a manner than ninimizes or eliminates potential health risks. The municipalities dispose off their partly treated r untreated wastewater into natural drains joining lakes or streams or used on land for irrigation. oxic chemicals from wastewater transfer to plants and entire in the food chain and affect public ealth. Therefore, wastewater can be considered as both a resource and problems (Salihu, 2008).

1.4 Objectives of the study

I. To analyze the physical and chemical properties of the soil before and after irrigating with wastewater to determine their effect on plant growth

II. To analyze and evaluate the physical and chemical properties of wastewater on plant growth.

1.5 Justification of the study

Irrigation farming is one of the most important means to enhance food supply should be done to ensure availability of water for the exercise, which in turn reduces poverty drastically and change the living standard of the general populace.

The high nutritive value of wastewater which has eliminated or reduced the needs for expensive chemical fertilizer is a great advantage over fresh water.

The use of wastewater for irrigation is not a common practice in this part of the world so farmers need to be enlightened on how wastewater can be safely use for irrigation and also its effect on the growth of plant.

1.6 Scope of the study

This study tends to analyze the impact assessment of wastewater irrigation on crop growth in kpakungu area of minna the capital of Niger state.

CHAPTER TWO

2.0 LITERATURE REVIEW

Farmers have used wastewater for irrigation to compensate for scarce or costly freshwater resources. Roughly10 % of the world's wastewater is currently being used for irrigation. In developing countries, especially China and India, an estimated 80% of wastewater may be used for irrigation (Ajibola, 2005). The quality of wastewaters must be closely evaluated and frequently checked to protect human health, and to prevent damage to crops and soils. Laws in some locations prohibit the use of wastewater, while in other locations, sewage effluent that has received the required treatment may be used the same as any other source. Benefits occur when wastewaters contain quantities of nitrogen, potassium and phosphates that reduces crop fertilizer requirement (Salihu, 2008).

Spray irrigation is the common method of applying wastewater to land. Ridge and furrow and border strip irrigation are also used. Application of wastewater in spray irrigation is generally limited to 8 hours followed by a 40 hours rest period to permit drainage of the soil, reparation, plant nutrient uptake and microbial readjustment. Wastewater disposal is by evapotranspiration and percolation plays the major role. Phosphorus and cadmium are accumulated by plants cadmium in particular, may be hazardous in edible crops. Physical, biological and chemical treatment takes place during percolation, particularly in the upper soil, including BOD and COD removal. Dissolved solids and chlorides may cause a soil problem where these constituents are high in wastewater. Cadmium levels should be kept below 2.5mg/kg in the soil. Sewage and soil analyzes should be made, as a soil PH below 7.0 facilitates cadmium uptake by crops and ridge and furrow ditches are on a grade from 30m to 45m in length. Depth and spacing varies with of crop and soil ability to transmit water laterally. Border strips are 9m to 18m (Ajibola, 2005).

In some parts of country fresh water resources are getting polluted due to discharge in them of effluents from industry and urban sewage as well as according to a limited extent due to the leaching and runoff of chemicals used in agriculture. Such polluted waters when used for irrigation can be harmful to crops (Mangala et al., 2006).

2.1 Sources of Wastewater

W astewater is dilute mixture of various wastes from residential, commercial, industrial and other public places. It is essential to know its composition, quality and characteristics. Though, characteristic of wastewater depends up to the source of its discharge, sewage in general contains organic matter, inorganic matter and living organisms. The organic and inorganic matters may be in dissolved, suspended and colloidal state. The organic or mineral matter consists of ash, cinder, sand, grit, mud and other mineral salts. The organic matter may be either nitrogenous or nitrogen free. The common sources of nitrogenous matter are urea and protein, while the nitrogen free compounds include carbohydrates, fats and soaps. The living organisms may be divided into plant life (such as algae, fungi) and animal life consisting of various types of micro-organisms such as protozoa, bacteria, virus e.t.c.

The composition or constituents of wastewater largely depends upon the source from which it is found in domestic wastewater that may be classified as strong, medium and weak, depending upon the concentration of the constituents. It should be noted that sewage contains only a very small percentage of solids in relation to huge amount of water. Liquid content of sewage is 99.9% while total amount of solids (Both suspended as well as dissolved) is only 0.1% (Mangala et al., 2006).

Table 2.1 Major Constituents of Typical Domestic Wastewater

CONSTITUENT	CONCENTRATION		
	Strong	Medium	Weak
Total solid	1200	700	350
Dissolved solid	850	500	250
Suspended solids	350	220	100
Biochemical oxygen demand	400	220	110
Chemical oxygen demand	1000	500	250
Nitrogen	85	40	20
Chlorides	100	50	30
Phosphorus	15	8	4
Organic carbon	290	160	80

Sources:Bhatia(2005)
All the constituents are mg/l,

According to Mohammed in 2007, the principal sources of domestic wastewater in a community are:

I. Residential areas

II. Commercial districts

Other important sources include institutional and recreational facilities. Wastewater flow rates are commonly determined from existing records or by direct field measurements.

2.1.1 Residential Areas,

Wastewater flow rates are commonly determined on population and average per capital contribution of wastewater. For residential areas where large residential development is planned, it is often advisable to develop flow rates on the basis of land use areas and anticipated population densities.

2.1.2 Commercial Districts,

Depending on the function and activity, unit flow rates for commercial facilities can vary widely. Unit flow rate allowances for commercial developments normally range from 7.5 to $14m^3$/ha-day (800 to 1500 gal/ac-d). The flow rates are generally expressed in terms of quantity of flow per unit area (m^3/ha-d (gal/ac-d)) (Ibitoye, 2008).

2.2 Characteristics of Wastewater,

Any waste or discarded material is technically worthless if it can not, in its current form be used. The value of waste is therefore potential rather than real and depends entirely on its ability to be reutilized. The value of recycling may be economical or social, usually the former. Water once used for any purpose on the earth can be re-used, at least for some purposes. Depending on the aim of the reuse, the water quality and quantities, treatment techniques, site and method of application are chosen. Sewage comprises a complex mixture of minerals and organic matter in many forms including large and small particles of floating and in suspension colloidal and pseudo-colloidal dispersions and true solution. Among the organic substances present in sewage are carbohydrates, fats, soaps synthetic and natural organic chemical from the process industries.

The characteristics of wastewater can be classified under the following three group:

i. Physical Characteristics

ii. Chemical Characteristics

iii. Biological Characteristics

2.2.1 Physical Characteristics: These are characteristics of wastewater that can be seen, felt or touched. They are usually easier to be determined compare to other forms of characteristics.

2.2.1.1 Total Solid: The most important physical Characteristics of wastewater is its total solids content, consisting of floating matter, matter in suspension, colloidal matter and matter in solution. Other physical characteristics are: smell or Odour, colour, temperature, turbidity, solid Content (Ibitoye, 2008).

2.2.1.2 Odour: This is the characteristic of wastewater that shows the level of actions of micro-organism in water. Normal fresh sewage has a musty odour which is normally not offensive, but as it starts to get stale, it begins to give offensive odour. Within 3 or 4 hours, all the oxygen present in the sewage gets exhausted and it starts emitting offensives odour of hydrogen sulphide gas and other sulphur compounds produced by anaerobic micro-organisms. Industrial wastewater may contain either process of wastewater treatment. Offensive odours can be harmful in many ways such as: Reduction in appetite for food, Lowering in water consumption, Impaired respiration, nausea and vomiting (Ibitoye, 2008).

Due to this, the elimination of odours has become a major consideration in the design and operation of wastewater collection, treatment and disposal facilities.

2.2.1.3 Colour: This is the parameter that indicates the presence of pollutants such as metals (e.g. inorganic acid from decaying vegetation), suspended solids or industrial waste. Fresh domestic sewage is grey, somewhat resembling a weak solution of soap. The colour of septic sewage is more or less black or dark in colour. The colour of industrial wastewater depends upon the chemical process in the industries. Industrial wastewater when mixed with domestic sewage, may also add colour to it (Ibitoye, 2008).

2.2.1.4 Temperature: It shows the relative degree of heat in the wastewater. Generally, the temperature of wastewater is higher than that of the water supply, due to addition of warm from the households and industries (Ibitoye, 2008).

2.2.1.5 Turbidity: This is a physical parameter which measures the relative clarity of a liquid or water sample. The turbidity depends upon the strength of sewage or wastewater. The stronger or more concentrated the sewage, the higher is its turbidity. It can also be referred to as the total salt concentration of a water sample. It is one of the most important agricultural water quality parameters. Plant growth, crop yield and quality of produce are affected by the total dissolved salt in the irrigation water (Ibitoye, 2008).

2.2.2 Chemical Characteristics: Sewage contains complex organic matters derived from urine, faeces e.t.c and inorganic chemicals. Fresh domestic sewage is slightly alkaline but tends towards acidic as it becomes stale. The important chemical characteristics of wastewater are: pH Value, Chloride Content, Nitrogen Content, Fats, Grease and Oil Content, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO) (Ibitoye, 2008).

2.2.2.1 pH Value: This is a unit that describe the degree of acidity or alkalinity of a solution. The test for pH Value of wastewater is carried out to determine whether it is acidic or alkaline in nature (its pH Value between 7.3 to 7.5). It tends to fall due to production of acids by bacteria action and the sewage tends to become acidic. However, after oxidation when it is relatively stable, it becomes alkaline again. A high concentration of either an acid (pH less than 7) or alkali (pH greater than 7) is indicative of industrial wastes (Ibitoye, 2008).

2.2.2.2 Chloride Content

This is toxic ion. Irrigation water that contains certain amount of this ion at threshold values can cause plant toxicity problems such as impaired growth, reduced yield, changes in morphology of plant and even death. Hence the concentrate of this ion will have to be determined to access its suitability for irrigation purposes (Salihu, 2008).

2.2.2.3 Nitrogen Content

The presence of nitrogen in wastewater indicates the presence of organic matter in it. Nitrogen is essential to the growth of prostista and plant (Salihu, 2008).

2.2.2.4 Fats, Grease and Oils

Fats and oil are mainly contributed from kitchen wastes because they are major component of food stuff such as butter margarine, vegetable, oil and fats. Fats are also commonly found in meat, seed, nuts and some seed grease and oil are also discharge from industries like motor parks, workshop and factories e.t.c Fats and oil are compounds (esters) of alcohol or glycerol with fatty acids (Salihu, 2008).

2.2.2.5 Biochemical Oxygen Demand (BOD)

The biochemical oxygen demand in sewage or water meant the amount of oxygen which is consumed during the self purification process to the oxidation of organic pollutants. The fact that biochemical oxidation processes are the most important for the removal of pollutants from sewage and water, they are of the essential importance for the improvement of sewage and water (Ibitoye, 2008).

2.2.2.6 Chemical Oxygen Demand (COB)

Chemical oxygen demand is an analytical parameter of pollution which measures chemically oxidized material in a liquid sample. The COD test is based upon the fact that all organic compounds with a few exceptions can be oxidized quantitatively by strong oxidizing agents (Ibitoye, 2008).

2.2.2.7 Dissolved Oxygen

Molecules of oxygen in water is crucial for plant to survive. Dissolved oxygen between 910ppm is considered very high while below 4ppm is very bad for the organisms living in the water (Ajibola, 2005). If dissolved oxygen is too low in wastewater, that is an indication that the bacteria concentration is high, and if used for irrigation, portends danger to crops and eventually consumers of the crops.

2.2.3 Biological Characteristics: Domestic sewage by its nature contains enormous quantities of micro-organisms. Some important biological characteristics are group as follows: Microbiological parameters, Natural physio-chemical parameters and Organoleptic parameters (Ibitoye, 2008).

2.2.3.1 Microbiological Parameters

These parameters are the most significant in determining water quality for potable supply standards for microbiological quality are essential based on the need to ensure that bacteria indicative of pollution by wastes are absent (Ibitoye, 2008).

2.2.3.2 Natural Physio-Chemical Parameters

These are normal characteristics of water such as pH, conductivity, total solid, alkalinity, hardness and dissolved oxygen.

2.2.3.3 Organoleptic Parameters

These are characteristics readily observable by the consumer but usually having little health significance, examples are colour, turbidity, taste and odour.

2.3 Sewage Water and Crop (vegetables)

Ajibola in 2005, carried out an experiment on the use of wastewater for irrigation of crops and agricultural soil. He observed that wastewater irrigation resulted in increased seed yield of crops except in certain season (i.e. when the wastewater is highly concentrated) which showed a decrease in seed yield of vegetable. The soil irrigated with wastewater showed no significant changes in pH, total organic carbon, cation exchange capacity, micro and macronutrients. It was concluded that treated wastewater met the irrigation requirement as its physico-chemical characteristics were within permissible limits.

Ajibola also presented an experiment conducted by Aref and Duogdorg in 1996 on comparative study to evaluate the effect of irrigation of treated wastewater on vegetable viral diseases. The result showed that treated wastewater gave an improvement in growth in both healthy and infected vegetables and a considerable yield increase

2.4 Implication of Wastewater Reuse on Health

Recycling of wastewater in agriculture is now viewed as a solution to conserve water resources to meet up the future shortages. The latest estimate of 22,900 million litre per day of water generated, only about 26% was treated before letting out, the rest was disposed of untreated. The mode of disposal of the 118(52%) cities was indirect disposal into river; in 63(28%) cities the wastewater was chanelled to the agriculture land, in 41 cities, it is discharged into streams and on agriculture land. Multiple use and integrated water management of such water is required to maintain the soil quality and health of human. The chloride content concentration of more than 1.0mg/l in drinking water adversely affects bones and teeth of human. Besides fluoride, arsenic pollution in irrigation water has also been observed, particularly in west Bengal and the use of arsenic water for crop production has serious implication for human health as it gets translocated in food chain (Mangala et al, 2006).

2.5 Contamination of Crops

The bacteria, protozoa and helminthes do not penetrate heavily undamaged surface of crops and then die away rapidly in crops, surface exposed to sunlight, pathogens can survive for extended periods inside leafy crops of unprotected stems. It is quite clear from many studies to date that pathogens are present in wastewater and can survive for long period in the soil or on crops. It is thus apparent that irrigation of health sensitive crops, including fruits and vegetables eaten uncooked, with raw or partly treated wastewater can present real health risks (Salihu, 2008).

2.6 Effects of Wastewater Reuse on soil

Irrigation with wastewater and presence of pesticide residues and heavy metals such as chromium, lead, manganese, copper and nickel from applied nutrients are the major causes of soil pollution. The easy availability of the subsidized inorganic nutrients over time and its effectiveness in increasing yields associated with increasing cropping intensity has resulted in reduced use of organic and green manures and sometimes, even burning of organic residues in the field. It is therefore, not surprising that farmers have to apply more fertilizers to get the same yield in the region. Many fertilizers, phosphatic fertilizers, in particular, contain varying amount of trace elements such as arsenic, cadmium, chromium, mercury, nickel and lead. These potentially harmful elements (Trace and Heavy metal) may accumulate in soil and may cause long term effects on crops yields and quality and may damage soil micro-flora. Through food, harmful elements may also get into human and cause health problem (Mangala et al, 2006). Harmful elements may accumulate in soil and may cause long term effects on crops yields and quality and may damage soil micro-flora. Through food may also get into human and cause health problem (Mangala et al, 2006).

2.7. Wastewater Irrigation Practices

In addition to mitigating possible health effects associated with the use of wastewater in agriculture, good irrigation practices will need to be followed to ensure a good crop yield and minimize risks to the environment. Irrigation practices with wastewater or with other water sources are similar and depend on the local conditions, including climate, physical and chemical soil properties, drainage conditions and the salt tolerances of the crops to be grown. Good wastewater irrigation practices will vary but are based on water quantity, water quality, irrigation techniques, crop selection, soil characteristics and management practices.

2.7.1 Water Quantity

The amount of wastewater available for irrigation will ultimately determine what types of crops can be grown and what types of irrigation techniques can be used. Most water applied to crops is lost by evapotranspiration from the plant surface. Therefore, the water required by the crops is usually equal to the amount of water lost by evapotranspiration. The evapotranspiration requirement is largely dependent on crops and climatic factors and this can be estimated based on local meteorological data (Tanji and Kielen (2002). FAO has developed a computer program (CROPWAT) to help farmers determine crop water requirements based on climatic factors. The appropriate quantity of water to use will need to be adjusted for the amount of rainfall, leaching requirements, application losses and other factors (Pescod, 1992).

Crops have different sensitivities to water supply. For example, groundnuts (peanuts) and some flowers have low sensitivities to water supply, while rice and bananas have high sensitivities to water supply.

2.7.2 Water Quality

Often, the limits on concentrations of many chemicals in the wastewater will be determined by crop requirements and not by health concerns. The nutrients in wastewater (i.e nitrogen, potassium, phosphorus, zinc, boron and sulphur should be present in the right concentrations, or they can damage the crops and/the environment. For example, wastewater often contains high concentrations of nitrogen. Although crops require nitrogen for growth, excessive nitrogen can cause overstimulation of growth, delayed maturity or poor- quality produce. Plants require different amounts of nitrogen based on their growth stage. In the first stages of growth, plants may require high quantities of nitrogen (in the earliest stages of growth, plants require lots of nitrogen, but may be too small to usefully assimilate all that is applied), but in the later flowering and fruiting stages, they may require less. In some cases, nitrogen levels will need to be adjusted by blending water supplies (Tanji and Kielen, 2002). This is also an important consideration to reduce leaching of nitrate into groundwater supplies, which would pose a potential health risk to consumers of the drinking-water.

Table 2.1 Water quality for irrigation

Parameter		Units	Degree of restriction on use		
			None	Slight to Moderate	Severe
Salinity EC_w[a]		dS/m	<0.7	0.7-3.0	>3.0
TDS		mg/l	<450	450-2000	>2000
TSS		mg/l	<50	50-100	>100
SAR	0-3	meq/l	$>0.7C_w$	$0.7\text{-}0.2C_w$	$<0.2EC_w$
SAR	3-6	meq/l	$>1.2EC_w$	$1.2\text{-}0.3EC_w$	$<0.3EC_w$
SAR	6-12	meq/l	$>1.9EC_w$	$1.9\text{-}0.5EC_w$	$<0.5EC_w$
SAR	12-20	meq/l	$>2.9EC_w$	$2.9\text{-}1.3EC_w$	$<1.3EC_w$
SAR	20-40	meq/l	$>5.0EC_w$	$5.0\text{-}2.9EC_w$	$<2.9EC_w$
Sodium(Na^+)	Sprinkler irrigation	meq/l	<3	>3	
Sodium(Na^+)	Surface irrigation	meq/l	<3	3-9	>9
Chloride(Cl^-)	Sprinkler irrigation	meq/l	<3	>3	
Chloride(Cl^-)	Surface irrigation	meq/l	<4	4-10	>10
Chloride(Cl2)	Total residual	mg/l	<1	1-5	>5

Bicarbonate(HCo_3^-)		mg/l	<90	90-500	>500
Boron (B)		mg/l	<0.7	0.7-3.0	>3.0
Hydrogen Sulfide(H_2S)		mg/l	<0.5	0.5-2.0	>2.0
Iron (Fe)	Drip irrigation	mg/l	<0.1	0.1-1.5	>1.5
Manganese(Mn)	Drip irrigation	mg/l	<0.1	0.1-1.5	>1.5
Total Nitrogen		mg/l	<5	5-30	>30
pH				Normal range 6.5-8	

Sources: Tanji el al. (2002)
TDS, total dissolved solid; TSS, Total suspended solids.
[a]ECw means electrical conductivity in decisiemens per metre at 25°C
SAR means Sodium adsorption ratio ([meq/l]1/2)

Sodium chloride, boron and selenium should be monitored carefully. Many plants are sensitive to these substances. Boron is frequently present in wastewater because it used in household detergents. Many types of trees (e.g citrus and stone fruits) will have impaired growth even when low boron concentrations are present are present in the water. Selenium can be toxic to plants in very low concentrations and can accumulate in plant tissue to toxic concentrations, for example alfalfa grown for forage (Tanji and kielen, 2002). Concentrations of these elements in irrigation water may be improved by blending water supplies if other sources are available (Tanji and kielen, 2002).

Water quality is also a factor in selecting the type of irrigation method. For example sprinkler irrigation with water that contains relatively high concentrations of sodium or chloride ions can cause leaf damage to sensitive crops, especially when climatic conditions favour evaporation (i.e high temperatures and low humidity). Similar damage to crops occurs when wastewater with high levels of residual chlorine (>5 mg/l) is sprayed directly onto leaves (Pescod, 1992).

Municipal wastewater may contain a range of other toxic substances, including heavy metals, as a result of industrial effluents entering the municipal wastewater stream (Drakatos et al. 2002). Some of these substances may be removed during wastewater treatment processes when available, but others may remain in quantities large enough to cause toxicity to the crops. In cases where industrial wastes are released into the general wastewater stream or where crops exhibit signs of trace element toxicity, it may be necessary to test the water and soil for these elements. Heavy metals are usually fixed by soil matrix and tend to be mobile only in the topmost soil layers. When water containing toxic trace elements is applied to crops, these elements may be concentrated in the soil as the water is lost into the atmosphere (Tanji and kielen, 2002).

Table 2.2 Threshold levels of trace elements for crop production

Element	Recommended Maximum Concentration(mg/l)	Remarks
Al Aluminium	5.0	Can cause non-productivity in acid soils ($pH<5.5$), but more alkaline soils at $pH>7.0$ will precipitate the ion and eliminate any toxicity.
As Arsenic	0.10	Toxicity to plants varies widely, ranging from 12mg/l for sudan grass to less than 0.05mg/l for rice.
Be Beryllium	0.10	Toxicity to plants varies widely, ranging from 5mg/l for kale to 0.5mg/l for bush beans.
Cd Cadmium	0.01	Toxic to beans, beets and turnips at concentrations as low as 0.1mg/l in nutrients solutions. Conservative limits recommended due to its potential for accumulation in plants and soils to concentration that may be harmful to humans.
Co Cobalt	0.05	Toxic to tomato plants at 0.1mg/l in nutrient solution. Tends to be

			inactivated by neutral and alkaline soils.
Cr	Chromium	0.10	Not generally recognized as an essential growth element. Conservative limits recommended due to lack of knowledge on its toxicity to plants.
Cu	Copper	0.20	Toxic to a number of plants at 0.1-1.0mg/l in nutrient solutions.
F	Fluoride	1.0	Inactivated by neutral and alkaline soils.
Fe	Iron	5.0	Not toxic to plants in aerated soils, but can contribute to soil acidification and loss of availability of essential phosphorus and molybdenum. Overhead sprinkling may result in unsightly deposits on plants, equipment and buildings.
Li	Lithium	2.5	Tolerated by most crops up to 5mg/l mobile in soil. Toxicity to citrus at low concentrations (<0.075mg/l). Acts similarly to boron.
Mn	Manganese	0.20	Toxic to a number of crops at a few-tenths to a few mg/l, but usually only in acid soils.
Mo	Molybdenum	0.01	Not toxic to plants at normal

			concentrations in soil and water. Can be toxic to livestock if forage is grown in soils with high concentrations of available molybdenum.
Ni	Nickel	0.20	Toxic to a number of plants at 0.5-1.0mg/l, reduced toxicity at neutral or alkaline pH.
Pd	Lead	5.0	Can inhibit plant cell growth at very high concentrations.
Se	Selenium	0.02	Toxic to plants at concentrations as low as 0.025mg/l, and toxic to livestock if forage is grown in soils with relatively high levels of added selenium. Essential element to animals, but in very low concentration
V	Vanadium	0.10	Toxic to many plants at relatively low concentrations
Zn	Zinc	2.0	Toxic to many plants at widely varying concentrations, reduced toxicity at pH>6.0 and infinite texture or organic soil.

Source: kalavrouziotis and Drakatos, 2002

2.7.3 Surface Irrigation

The practice of surface irrigation is thousands of years old (Stirzaker, 2003). It collectively represents perhaps as much as 95 percent of common irrigation activity today. The first water supplies were developed from stream or river flows onto the adjacent flood plain through simple check-dams and a canal to distribute water to various locations where farmers could then allocate a portion of the flow to their fields. The low-lying soils served by these diversions were typically high in clay and silt content and tended to be most fertile. The land slope was normally small because of the structure of the flood plain itself.

With the advent of modern equipment for moving earth and pumping water, surface irrigation systems were extended to upland areas and lands quite separate from the flood plain of local rivers and streams. These lands tend to have more variable soils and topographies, are usually better drained, and may be naturally less fertile. Thus, these lands usually require greater attention to design and operation.

Advantages of Surface irrigation

Surface irrigation offers a number of important advantages at both the farm and project level. Because it is so widely utilized, local irrigators generally have at least minimal understanding of how to operate and maintain the system. In addition, surface systems are often more acceptable to agriculturalists who appreciate the effects of water shortage on crop yields since it appears easier to apply the depths required to refill the root zone.

The second advantage of surface irrigation is that these systems can be developed at the farm level with minimal capital investment. The control and regulation structures are simple, durable and easily constructed with inexpensive and readily-available materials like wood, concrete, brick and mortar, etc. Further, the essential structural elements are located at the edges of the fields which facilitates operation and maintenance activities. The major capital expense of the surface system is generally associated with land grading, but if the topography is not too undulating, these costs are not great. Recent developments in surface irrigation technology have largely overcome the irrigation efficiency advantage of sprinkler and trickle systems. An array of automating devices roughly equates labour requirements. The major trade-off between surface and pressurized methods lies in the relative costs of land levelling for effective gravity distribution and energy for pressurization. Energy requirements for surface irrigation systems come from gravity. This is a significant advantage in today's economy.

Another advantage of surface systems is that they are less affected by climatic and water quality characteristics. Even moderate winds can seriously reduce the effectiveness of sprinkler systems. Sediments and other debris reduce the effectiveness of trickle systems but may actually aid the performance of the surface systems. Salinity is less of a problem under surface irrigation than either of these pressurized systems.

There are other advantages specific to individual regions that might be mentioned. Surface systems are better able to utilize water supplies that are available less frequently, more uncertain, and more variable in rate and duration. The gravity flow system is a highly flexible, relatively easily-managed method of irrigation.

Disadvantages of Surface irrigation

There is one disadvantage of surface irrigation that confronts every designer and irrigator. The soil which must be used to convey the water over the field has properties that are highly varied both spatially and temporally. They become almost undefinable except immediately preceding the watering or during it. This creates an engineering problem in which at least two of the primary design variables, discharge and time of application, must be estimated not only at the field layout stage but also judged by the irrigator prior to the initiation of every surface irrigation event. Thus while it is possible for the new generation of surface irrigation methods to be attractive alternatives to sprinkler and trickle systems, their associated design and management practices are much more difficult to define and implement.

Although they need not be, surface irrigation systems are typically less efficient in applying water than either sprinkler or trickle systems. Many are situated on lower lands with heavier soils and, therefore, tend to be more affected by waterlogging and soil salinity if adequate drainage is not provided. The need to use the field surface as a conveyance and distribution facility requires that fields be well graded if possible. Land levelling costs can be high so the surface irrigation practice tends to be limited to land already having small, even slopes.

Surface systems tend to be labour-intensive. This labour need not be overly skilled. But to achieve high efficiencies the irrigation practices imposed by the irrigator must be carefully implemented. The progress of the water over the field must be monitored in larger fields and good judgement is required to terminate the inflow at the appropriate time. A consequence of poor judgement or design is poor efficiency.

One sometimes important disadvantage of surface irrigation method is the difficulty in applying light, frequent irrigations early and late in the growing season of several crops. For example, in heavy calcareous soils where crust formation after the first irrigation and prior to the germination of crops, a light irrigation to soften the crust would improve yields substantially. Under surface irrigation systems this may be unfeasible or impractical as either the supply to the field is not readily available or the minimum depths applied would be greater.

The term 'surface irrigation' refers to a broad class of irrigation methods in which water is distributed over the field by overland flow. A flow is introduced at one edge of the field and covers the field gradually. The rate of coverage (advance) is dependent almost entirely on the differences between the discharge onto the field and the accumulating infiltration into the soil. Secondary factors include field slope, surface roughness, and the geometry or shape of the flow cross-section.

2.7.4 Crops selection

The yields of many crops may be as much affected by how water is applied as the quantity delivered. Irrigation systems create different environmental conditions such as humidity, temperature, and soil aeration. They affect the plant differently by wetting different parts of the plant thereby introducing various undesirable consequences like leaf burn, fruit spotting and deformation, crown rot, etc. Rice, on the other hand, thrives under ponded conditions. Some crops have high economic value and allow the application of more capital-intensive practices. Deep-rooted crops are more amenable to low-frequency, high-application rate systems than shallow-rooted crops.

2.7.5 Social influences

Beyond the confines of the individual field, irrigation is a community enterprise. Individuals, groups of individuals, and often the state must join together to construct, operate and maintain the irrigation system as a whole. Within a typical irrigation system there are three levels of community organization. There is the individual or small informal group of individuals participating in the system at the field and tertiary level of conveyance and distribution. There are the farmer collectives which form in structures as simple as informal organizations or as complex as irrigation districts. These assume, in addition to operation and maintenance, responsibility for allocation and conflict resolution. And then there is the state organization responsible for the water distribution and use at the project level.

Irrigation system designers should be aware that perhaps the most important goal of the irrigation community at all levels is the assurance of equity among its members. Thus the operation, if not always the structure, of the irrigation system will tend to mirror the community view of sharing and allocation.

Irrigation often means a technological intervention in the agricultural system even if irrigation has been practiced locally for generations. New technologies mean new operation and maintenance practices. If the community is not sufficiently adaptable to change, some irrigation systems will not succeed.

2.7.6 External influences

Conditions outside the sphere of agriculture affect and even dictate the type of system selected. For example, national policies regarding foreign exchange, strengthening specific sectors of the local economy, or sufficiency in particular industries may lead to specific irrigation systems being utilized. Key components in the manufacture or importation of system elements may not be available or cannot be efficiently serviced. Since many irrigation projects are financed by outside donors and lenders, specific system configurations may be precluded because of international policies and attitudes.

The preceding discussion of factors affecting the choice of irrigation systems at the farm level is not meant to be exhaustive. The designer, evaluator, or manager of irrigation systems should be aware of the broader setting in which irrigated agriculture functions. Ignorance has led to many more failures or inadequacies than has poor judgement or poor training.

As the remainder of this guide deals with specific surface irrigation issues, one needs to be reminded that much of the engineering practice is art rather than science. Experience is often a more valuable resource than computational skill, but both are needed. It is a poor engineering practice that leaves perfectly feasible alternatives just beyond one's perspective.

2.8 Soil

2.8.1 What is Soil?

Soil is generally referred to as the topmost part of the earth crust (Ibitoye, 2008). According to Ajibola (2005) soil is the loose material that covers the land surface earth and supports the growth of plants. In general, soil is an unconsolidated, or loses, combination of inorganic and organic materials.

2.8.2 Soil Characteristics

2.8.2.1 Soil infiltration

The infiltration rate of the soil determines how much water will reach the crop root zone and eventually percolates to the subsoil and is dependent upon soil texture and structure and the structural stability of the soil. The infiltration rate is also dependent upon both the salinity of the water and the sodium adsorption ratio (SAR) of the soil. (See table 1.1). The SAR is a measure of the ratio of sodium ions to calcium and magnesium ions in the soil. The SAR can be calculated using the following formulae:

$$SAR = Na^{+} / [(Ca^{++} + Mg^{++})/2]^{1/2}$$

Where the ionic concentrations of Na, Ca and Mg are expressed in Meq/l.

Water with a low salinity content (<0.5 dS/m) leaches soluble minerals and salts. If calcium is leached, soil structure can be destabilized and fine soil particles become dispersed.

These fine soil particles clog the pore spaces. This leads to reduced water infiltration rates, soil crusting and crop emergence problems (Drakatos et al, 2002). Water with excessive sodium (relative to the concentration of total dissolved salts in the soil) also will impair water infiltration. Water infiltration problems usually occurs in the top 10cm of the soil (Drakatos et al, 2002).

2.8.2.2 Soil Profile

Soils develop horizons or layers of distinct characteristics through soil forming processes. They are commonly referred to as the A, B, and C-horizons. The A-horizon is a layer that has been leached of soluble salts and clay but has accumulated organic matter through its high biological activity. The higher concentration of organic matter gives it a darker appearance than other horizons. The B-horizon occurs between the A and C. It commonly has an accumulation of clay compared to the A and C horizons. The A and B horizon are considered the solum or true soil. The C-horizon, also called parent material, shows little biological activity or soil development other than mineral decomposition of rock.

Climate and biological factors generally produce broad geographic patterns of soils (zonality). Parent material or geology from which soils form also affects the patterns of occurrence at regional and local levels. Topographic patterns (landscape) add further complexity, affecting both the time of exposure to processes of soil formation and the kinds of process (Tabor, 2001).

The scale most useful for management of soils is a farmer's field or a building site. Using this scale, land managers have identified natural transitions between contrasting characteristics and developed classification systems to pigeonhole soils with similar properties. The USDA soil classification system, *Soil Taxonomy*, defines pedon as the smallest body of one kind of soil large enough to represent the nature and arrangement of horizons and variability in the other properties that are preserved in samples(Stirzaker, 2003). A pedon extends down to the lower limit of a soil. It extends through all genetic horizons and, if the genetic horizons are thin, into the upper part of the underlying material. The pedon includes the rooting zone of most native plants. For purposes of most soil surveys, a practical lower limit of the pedon is bedrock or a depth of about 2 m, whichever is shallower. A depth of 2 m provides a good sample of major soil horizons, even in thick soil. It includes much of the volume of soil penetrated by plant roots, and it permits reliable observations of soil properties.

The surface of a pedon is roughly polygonal and ranges from 1 m^2 to 10 m^2 in area, depending on the nature of the variability in the soil. Where the cycle of variations is less than 2 m and all horizons are continuous and nearly uniform in thickness, the pedon has an area of approximately 1 m^2. Where horizons of other properties are intermittent or cyclic over an interval of 2 to 7 m, the pedon includes one-half of the cycle (1 to 3.5 m). If horizons are cyclic over an interval greater than 7 m, each cycle is considered to contain more than one soil. The range in size, 1 to 10 m^2, permits consistent classification by different observers where important horizons are cyclic or repeatedly interrupted over short distances (Tabor, 2001).

Soil maps delineate areas that have high percentages of the same soils as defined by the map's classification system and legend. Rarely do they delineate units that are 100% pure. Soils maps can provide useful information for planning if the scale and classification criteria are appropriate. However, if the map is used for other than its intended purpose, final decisions such as project design and good management will depend on site investigations of important soil properties and knowledge of how they relate to management.

There are many soil properties that are important to use and management. Some of them are listed below with a few of the more important ones described later.

- chemistry: cation exchange capacity, pH, availability of plant macronutrients (nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur) and micronutrients (iron, manganese, copper, zinc, boron, molybdenum, chlorine, and cobalt), sodium content, clay mineralogy, percent base saturation, percent organic carbon, etc.
- physics: texture, water holding capacity, saturated and unsaturated hydraulic conductivity,

water infiltration rate, bulk density or apparent specific gravity, particle density or true specific gravity, porosity, moisture content, Proctor density curve, structure, shrink-swell potential, modulus of rupture, compressive strength, plasticity index, cohesion, matric and osmotic potentials of water, etc.

- biology: yield per hectare (tons of maize, wheat, cotton, etc.), soil seed bank, biodiversity (mycorrhizae, nitrogen fixation bacteria, etc.).

2.8.2.3 Texture

Texture, or the grain size composition of minerals that help make up a soil, is one of the most important properties of a soil because it is related to many other properties. Knowing the texture of a soil gives one an idea about its other properties. The USDA system separates texture into four major classes: **coarse fragments** (gravels, stones, and boulders; greater than 2 mm in diameter), **sand** (the stuff beaches and dunes are mostly made of; 2 mm to 0.05 mm in diameter), **silt** (one can't see the individual grains, the main component of dust and feels like flour; 0.05 mm to 0.002 mm in diameter), and **clay** (pure moist clay looks and feels like fresh axle grease and 30 to 40% clay in the soil will make it plastic like modeling clay; less than 0.002 mm in diameter) (Stirzaker, 2003).

The textural triangle is used to determine textural classes of soil for particles less than 2 mm in diameter (sands, silts, and clays). Each of its three axes ranges from 0 to 100% for each size fraction. To determine the textural class, estimate the percentages of the two easiest fractions sand, silt or clay and find where the intersection of the two occurs on the triangle. The following are descriptions of how some textural classes feel.

- **Sand**: Sand is loose and single-grained. The individual grains can readily be seen or felt. If squeezed when moist, it will form a cast (a coherent mass or body), but will crumble when touched.

- **Sandy loam**: Sandy loam is a soil containing much sand but which has enough silt and clay to make it somewhat cohesive. The individual sand grains can readily be seen and felt. Squeezed when dry it will form a cast which will readily fall apart, but if squeezed when moist a cast can be formed that will bear careful handling without breaking.
- **Loam**: Loam is a soil having a relatively even mixture of different grades of sand, silt, and clay. It has a somewhat gritty feel, yet is fairly smooth and slightly plastic (malleable like modeling clay). A squeezed moist cast can be handled quite freely without breaking.
- **Silt loam**: Silt loam is a soil having a moderate amount of fine grades of sand and only a small amount of clay. Over half the particles are of the size called "silt." When dry it may form clods that can be easily broken, and if pulverized it feels soft and floury. When wet the soil readily disperses and flows into puddles. Either dry or moist it will form casts that can be freely handled without breaking. When moistened and squeezed between thumb and finger it will not form a "ribbon" (a thin ribbon shaped mass of soil which easily forms if the soil is very cohesive) but will give a broken appearance.
- **Clay loam**: Clay loam is a fine textured soil which usually breaks into clods or lumps that are hard when dry. The moist soil is plastic and will form a cast that will bear much handling. When kneaded in the hand, it does not crumble readily but tends to form a heavy compact mass.
- **Clay**: Clay is a fine textured soil that usually forms very hard lumps or clods when dry and is quite plastic and sticky when wet. When the moist soil is pinched out between the thumb and

fingers it will form a long, flexible ribbon (Tabor, 2001).

2.9 Cation Exchange Capacity

Cation exchange capacity (CEC) refers to the negatively charged sites on the soil minerals and organic matter which attract and hold positively charged ions, including plant nutrients (K^{+1}, Ca^{+2}, NH_4^{+1}, Mg^{+2}, etc.) for uptake by roots. CEC is measured in milliequivalents (meq) per 100 grams of soil. Good agricultural soils in the US generally have CECs that range from 15 to 50 meq/100 g. Sandy, aridic soils commonly have CECs around 1 meq/100 g or less because the sand and silt of these soils contribute very little to the exchange capacity. Clay and organic matter contribute the most. Organic matter contributes 150 to 300 meq/100 g and clay contributes 8 to 100 meq/100 g depending on the type of clay mineral (kalonite, montmorillinite, etc.) (Tabor, 2001).

2.9.1 Water Holding Capacity

Water holding capacity (WHC) of the soil is mainly influenced by texture. A very sandy soil (greater than 80% sand) can hold 8 to 12% water, depending on the size of the sand particles. Any additional water would percolate out of the root zone or runs off the surface. A soil low in sand (less than 20%) can hold 18 to 20% water. Non-sandy soils allow plants more time between rainfall events or irrigations before they become stressed from lack of water (Tabor, 2001).

2.9.2 Drainage

To maintain a favourable salt balance, excess water must be able to drain from the surface and from the root zone. Excess water can damage plants and increase soil salinity. Good drainage is particularly important in arid and semi-arid areas. If land drainage is sufficient, the water table can rise. When the water table gets too close to the surface (within 2 m), during dry periods water can rise to the surface by capillary action, evaporate and leave behind dissolved salts. Salt accumulation in the soil reduces crop yields and can ultimately make the soil unfit for agriculture (Tanji and kielen, 2002). In areas where the water table is high and the groundwater has a high salinity, it may be necessary to construct open or tile drains to stabilize the depth of the groundwater. The long-term sustainability of irrigation with wastewater requires soils with good drainage (Drakatos, 2002). As the drainage water can contain components that may be harmful to the environment (e.g salts, pesticide and fertilizer residues), the quality of the drainage water should be controlled and must be disposed of properly, particularly if it is reused in agriculture or for other purposes (Tanji and kielen, 2002). Wescot in 1997 describes quality characteristics of drainage water from agriculture.

2.9.3 Management practices

Good management practices are important in any irrigation scheme. In addition to those practices previously described for controlling health impacts, it is also necessary for optimal plants growth to properly manage water application rates and timing, land and soil and crops. A summary of these considerations is presented below. It is necessary to manage water application rates and to time applications appropriately. It is important to:

- assess the water- holding capacity of the soil;
- assess the need for pre- and post- planting irrigation to avoid water stress and leach salts from soil prior to and after planting;
- maintain optimal soil moisture levels;
- estimate the evapotranspiration rate (mostly based on the prevailing climatic conditions-

e.g. radiation, temperature, humidity and wind speed);

- time water application appropriately-e.g. water can be applied at night to reduce losses to evaporation and reduce sodium and chloride toxicity to plants;
- determine the quantity of water to be applied, based on rainfall, drainage, soil infiltration, plant and leaching requirements;
- adjust the nitrogen level to match plant requirements through water blending;
- evaluate the irrigation method (e.g. water with residual chlorine applied via sprinkler irrigation can harm leaves of many plants);

Land and soil management are important for overcoming salinity, sodicity (sodium concentration in the soil) and toxicity to plant and reducing health hazards. The following practices need to be considered to optimize plants growth in specific condition:

- grading the land to reduce erosion and runoff;
- deep ploughing to break up compact soil pans and improve water movement through the soil;
- soil amendments to improve soil structure, drainage, infiltration or pH;

Crop management can also be used to improve yields. Irrigation with wastewater may require management practices similar to those for irrigation with saline water. Seed germination is most sensitive to soil salinity. Seeds can be placed in such a way as to minimize the impacts of soil salinity by:

- crop selection according to salt tolerance;

- planting seeds on the shoulder(s) of the ridge during furrow irrigation;
- planting seeds on the sloping side of seed beds (seed bed should be placed above the watersh Line);
- irrigating alternate rows so that salts move beyond the single seed row;
- choosing alternatives to furrow irrigation when the wastewater is highly saline.

CHAPTER THREE

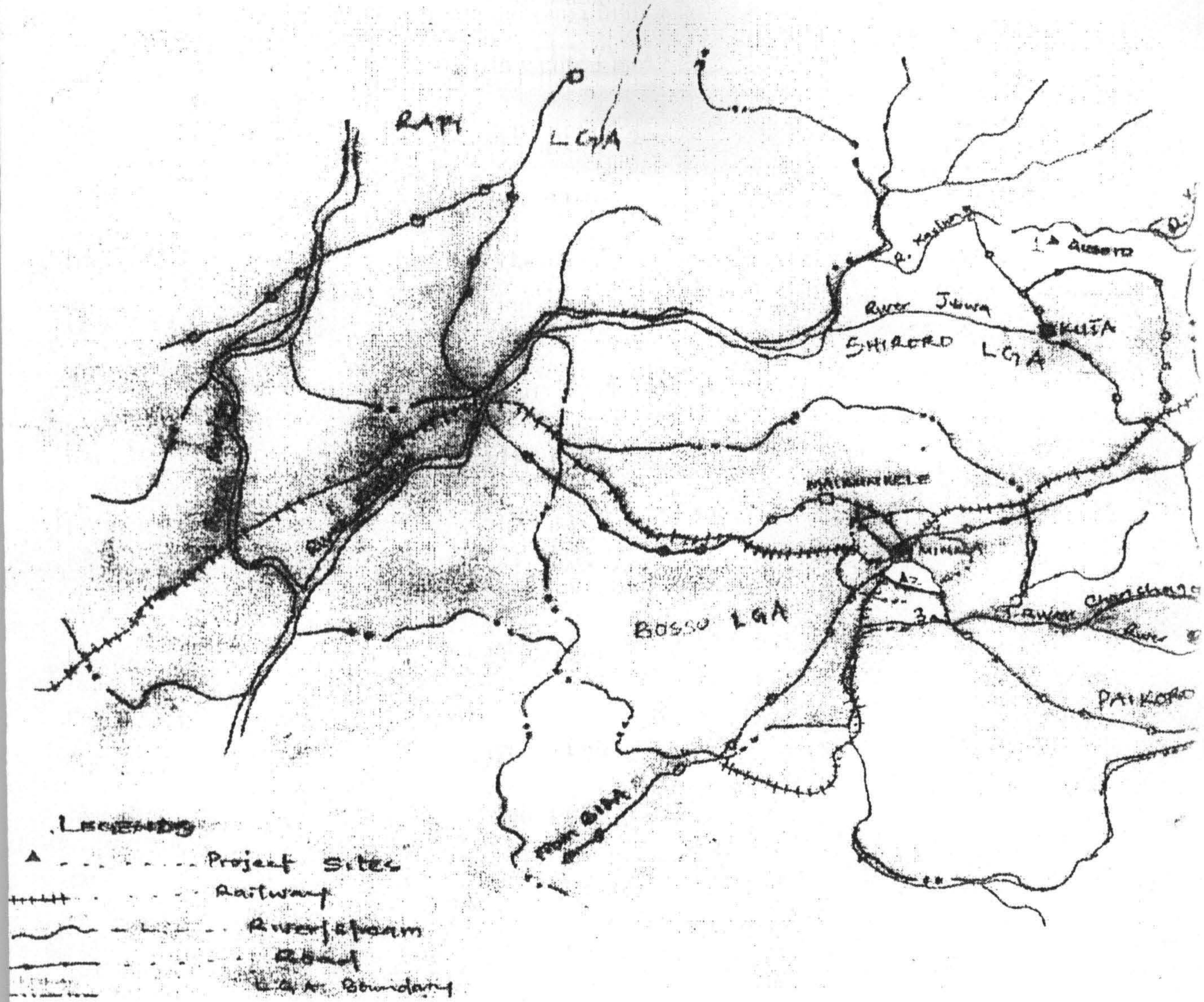
MATERIALS AND METHODS

3.1 Land Preparation

The experimental site was prepared in May 2009. Simple (local) tools (cutlass, hoe, shovel and rake) were used to clear the land and prepare the seed bed on the same day. The slope of the land was approximately 5%.

3.2 Description of the Study Area

The study area is located in kpakungu, Bosso Local Government Area Niger state, Nigeria. Niger state is situated in North Central part of the Federal Republic of Nigeria. It lies in the Savanna Zone of the tropics between latitude 8^0 10^1N and 11^0 30^1 N and longitude $3^0 30^1$ and $7^0 30^1$ E (Fig 3.1). Its climate is influence mainly by the rain-bearing South West monsoon winds from the oceans and the dry dusty or Harmattan North East winds (air masses) from the Sahara Desert. There are mainly the rainy and the dry seasons. The rainy season begins in April and ends in October and the dry season starts in November and ends March. The mean monthly rainfall record from 1998 to 2008 ranges from 0.57mm to 215.1mm with February/March having the minimum and September having the maximum occurrence (Appendix A). The nature of the soil is loamy and the wastewater used flows continuously from domestic/residential area of kpakungu (through the bridge) to other parts of Minna metropolis. The size of the plot is 1.83m by 2.44m.



ig 3.1: An Abridge Map of Niger State Showing the Study Site [$\triangle_2$]

3.3 Experimental procedure

3.3.1 Water samplings

Five 150cl plastic containers were used for collection of water samples. The containers were initially washed with detergent and properly rinsed, and at the point of sampling the containers were rinsed with the water sample several times before the samples were finally taken, corked and labeled immediately, five samples were collected. The samples were collected by holding the containers at the lower part and submerging into an approximate depth of 20cm with the mouth facing towards the direction of flow of the water. The sample collected were taken to the Regional Water Quality Laboratory, Upper Niger River Basin Minna and were kept in a refrigerator before proceeding on the analysis test and average values were determined for all the parameters analyzed for.

3.3.1.1 Determination of physical properties of the wastewater

Here are the physical parameters that were analyzed for;

i. Total Dissolved Solid (TDS)
ii. Temperature
iii. Turbidity
iv. Colour

3.3.1.2 Determination of Chemical Properties of the wastewater

Chemical parameters analyzed for were;

Dissolved Oxygen, Conductivity, Suspended Solid, pH, Ammonia, Nitrate, Nitrite, Sodium, Potassium, Calcium Hardness, Magnesium Hardness, Hardness, Carbonate, Bicarbonate, Alkalinity, Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Hydroxide, Chloride, Flouride, Magnesium and Calcium.

3.3.2 Water Sampling Analyses for Physical and Chemical properties

3.3.2.1 Materials for Laboratory analysis

The equipments and materials used for this analysis ranges from complex computerized equipment to simple ones like the water containers. Some of the equipments include;

- Atomic absorption Spectrophotometer
- Incubator
- Autoclaves
- Bunsen burner
- Inoculating loop
- P^H meter
- Petri dishes
- Pipettes
- Reagent and chemicals
- Refrigerator
- Oven
- Desiccators
- Water containers.

3.3.2.2 Turbidity

A clean and dry sample vial was obtained and handled by the top, the vial was rinsed with about 10mL of the sample capping the vial with the black screw cap and inverted gently several times. This was discard and rinsing repeated. The rinsed vials were filled with a soft, link free clothe supplied and it was ensure that the outside of vial was free from smudges, clean and dry.

The JMP turbidity meter was placed on a flat and level surface was calibrated with the recommended standards. The prepared sample vial were placed and aligned, the vial's mark were aligned with the meter's index mark. The vial was pushed until it was fully snapped in. The vial was covered with the light shield cap and the meter turned on by pressing the ON/OFF key. After the power, sup sequence display blanks [...R...] for about 12seconds after which a value appears (turbidity value). Incase of a second vial, the sample should be inverted well and aligned with the vial's mark with the meter's index mark. The READ/ENTER KEY was pressed, the display blinks [...R...] and a value appeared, which was the turbidity value. This value was recorded.

NOTE

1. Do not clean sample well, because it may damage the optics.
2. Instrument automatically turns off about 20minutes if not used.
3. Always use a vial and never pour liquid directly into sample
4. Always use the black cap before taking reading because it serves as a shield from light

3.3.3.2 Colour

Monitoring colour was through observation. Although this parameter does not provides information about specific chemicals in water.

3.3.3.3 Temperature: Thermometer was used to determine the temperature

3.3.3.4 Electrical Conductivity

Method: Conductivity was measured using the conductivity meter CMD 800 hydro check conductivity meters. This apparatus apply a known voltage to the liquid by a suitable electrode system with a conductivity cell, measure the resultant current was measured and the conductivity was calculated using ohm's law.

3.3.3.5 Biological Oxygen Demand (BOD)

Method: The BOD trak method was an easy and direct method of measuring BOD. It makes complex chemical analysis unnecessary because the BOD trak instrument takes a physical measurement of the oxygen consumed by a test sample.

3.3.3.6 Chemical Oxygen Demand (COD)

Method: In the dichromate reactor digestion method test, the COD procedure is greatly simplified over the dichromate reflux method. Small volumes of water were pipetted into vials containing the pre measured reagent including catalyst and chloride compensator. The vials are incubated until digestion was completed and then cooled. The COD measurement was made with the spectrometer or by titration.

3.3.3.7 P^{H}:

In the laboratory the P^{H} of the water was measured using a P^{H} meter, the result obtained for all the samples was recorded.

Others are, Chloride: Argentometric method, Nitrite: Colorimetric method, Ammonia: Nesslerization method and Cadmium Reduction method was used for Nitrate.

3.4 Soil Samplings and Analyses

Five sampling points were randomly selected on the site, and one the control plot.The five points form one population. The distance between the points from each other was approximately four metres. The first samples (before irrigation) were taken on the same day the bedding was made using local tools (hoe,cutlass and shovel) and they were labeled appropriately. The second samples (after irrigation) were also taken using the same procedures.

The soil samples before being sent to the laboratory for analysis were treated by drying. The samples were spread out and air dried at room temperature for three days. At least 450g of each sample was sent for analysis. Analyses were carried out using glass electrode pH meter for the pH analysis, bouyoucos method for particle size analysis, macro-kjeldahl method for Nitrogen and other minerals.

3.5 Experimental protocol

The following physical parameters were used to determine the effect of the wastewater on the vegetable (Ammaranthus cruentus):

i. Length of stems of vegetable

ii. Greenness of mature leaves

iii. Leaf Area Index (LAI)

iv. Weight of vegetable

Plate 1. The prepared site for the experiment

3.6 Leaf Area Index (LAI)

Leaf Area Index (LAI) is one of the most important crop parameters in photosynthesis driving crop growth simulation model and canopy evapotranspiration. Simulation model, while air temperature and radiation are the important climate factors affecting crop leaf growth (Yong Sheng, 2008).

Leaf Area Index is the ratio of total upper leaf surface of vegetation divided by the surface area of the land on which the vegetation grows. LAI is a dimentionless value, typically ranging from 0 for bare ground to 6 for a dense forest.

$$\text{Thus Leaf Area Index} = \frac{\text{Total upper leaf surface of vegetation}}{\text{Surface Area of the land on which the vegetation grows}}$$

Leaf Area = Length of the Leaf x Breadth of the Leaf x The leaf coefficient

And

Area of the plot = 4.67 m^2, Average Length and Breadth are in table 4.4 and 4.5 respectively. And the Leaf Coefficient = 0.63.

3.7 Irrigation Interval and Amount of Water per Application

A general principle on which determination of irrigation interval is based is that plant cannot readily use more than half the available moisture in the soil and thus, irrigation is needed when this half is used up (Ajibola, 2005). Therefore, the amount of water to be applied by a particular crop in one irrigation application depends on soil and weather conditions of the site.

The quantities of wastewater applied was not the same (uniform) throughout the growing period because the experiment was carried out during raining season. Four 25litres containers of water were applied every four days in the morning on Experimental plot and the control and the volume reduced to Two 25litres when it rained from the growing period (week 1) to maturity stage (week 4) and surface irrigation method was used throughout the experiment.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Results

The Results of the analysis are given below:

Table 4.1: Results of Physical parameters of Wastewater Analysis

Parameters	Unit	Average Value
Temperature	0C	28.4
Total Dissolved Solid	Mg/L	414.73
Turbidity	NTU	19.79
Colour	TCU	246

4.2 Discussion of Results

4.2.1 Total Dissolved Solid (TDS)

The salt quantity in water sample is determined by Total Dissolved Solid. This is expressed in part per million (ppm) which is the same with weight of milligram per litre (mg/L). The Total Dissolved Solid affects the crop water availability which depends on salinity of the water.

The average value of the TDS obtained from the wastewater sample was 414.73. The value is within the recommended standard of FAO which ranges between 0-2000 mg/L. Therefore the water can be safely used for irrigation of the crop.

4.1.3 Temperature

Soil temperature appears to be more critical than water temperature when irrigating during hot weather. Commonly, you will hear irrigators say that it is not good to irrigate when irrigation water is warm, but it's okay when the water is cold. There are two reasons for this. Colder water holds more dissolved oxygen, and colder temperatures keep the vegetable demand for oxygen relatively low. Average value of 28.4 ^{0}C falls within the FAO (1992) recommended limit which makes the water sample suitable for crop growth.

4.1.4 Turbidity

Turbidity is a measure of the degree to which the water looses its transparency due to the presence of suspended particles. The more total suspended solids in the water, the murkier it seems and the higher the turbidity. The suspended particles absorb heat from the sunlight making turbid waters become warmer and so reducing the concentration of oxygen in the water. Average value of 19.79 NTU is on the high side (because the wastewater was from industrial, domestic and public area) when compare with the standard limit. Hence, the water needs to be treated to bring down and make it suitable for irrigation purposes.

Table 4.2: The Results of Chemical parameters of Wastewater Samples

Parameters	Unit	Average Value
Dissolved oxygen	ppm	3.55
Conductivity	ms/cm	619
Suspended solid	mg/L	21
pH		7.56
Ammonia	mg/L	41.21
Nitrate	mg/L	182.45
Nitrite	mg/L	0.805
Sodium	mg/L	31.5
Potassium	mg/L	15.41
Calcium hardness	mg/L	101
Magnesium hardness	mg/L	5
Hardness	mg/L	106
Carbonate	mg/L	0
Bicarbonate	mg/L	166
Alkalinity	mg/L	166
COD	mg/L	170
BOD_5	mg/L	16
Hydroxide	mg/L	0
Chloride	mg/L	23.98
Fluoride	mg/L	0.06
Magnesium	mg/L	1.1
Calcium	mg/L	40.48

4.3 Discussion of Results of Chemical Analysis of the Wastewater

4.3.1 The pH

pH is an indicator of the acidity or basicity of a water, but is seldom a problem by itself. The main use of pH in a water analysis is for detecting an abnormal water. An abnormal value is a warning that the water needs further evaluation as this can lead to nutritional imbalance. The average value obtained for the sample of wastewater was 7.56, which means that the sample was slightly alkaline and this may be due to low buffering capacity of the water. The pH recommended range for irrigation water is from 6.5 to 8.4 (FAO, 1994). The value obtained was within the recommended standard and thereby making the water safe for irrigation purposes

4.3.2 Potassium Content

Potassium ion is often present in significant amount in irrigation water. Being an essential nutrient, it acts in reducing the harmful effect of saline water on crop grown by providing the nutrient regularly, rather than reducing soil salinity. The average value obtained from the wastewater sample was 15.41 mg/L. This value is within the FAO recommended limit for irrigation water (FAO, 1994), which shows that the water portend no irrigation threat.

4.3.3 Nitrogen Content

Nitrogen in irrigation water has the same effect on soil as applied fertilizers, an excess of nitrogen in water for irrigation will have an adverse effect on the soil and planted crops. The normal range of nitrate-nitrogen (NO_3-N) in irrigation water is 0-10mg/l. Nitrogen reduces the harmful effect of saline water on crops by providing nutrient constantly and it also helps in mutilating the salt induced-nitrogen deficiency and in increasing crop germination and productivity. The nitrate (NO_3-N) value obtained from the sample of wastewater was 182.45

mg/l. This is on the high side when compare with FAO standard and the source of the wastewater (industries & domestic which known to be high in nitrogen) might be responsible for this. Thus the water needs to be treated to bring the level of its nitrogen content down for irrigation of crops.

4.3.4 Chloride Content

Chloride ion is normally useful in killing growing protozoan in water. The organism has adverse effect on germination and the normal plant growth. The average value obtained from the wastewater sample was 23.98 mg/l. This value is within the FAO recommended limit of 30 mg/l, which implies that the water is suitable for crops irrigation as far as Chloride content is concerned.

4.3.5 Calcium Content

Calcium expresses the total hardness of the water and helps in the classification of the water into soft or hard. The average value obtained from the sample of water was 40.48 mg/l. The permissible level recommended by FAO standard is 0-20 mg/l. Thus, this high calcium content exceeds the recommended range which implies that there might be potential irrigation problem because high calcium content leads to scale formation either on the leaves or fruits. Therefore, the water needs to be treated for hardness to reduce the calcium content of the water for suitability.

4.3.6 Bicarbonate Content

If the bicarbonate content of a water sample is high, the calcium and magnesium in the water sample may precipitate out as carbonate; thus reducing calcium and magnesium which in turn increase the sodium adsorption ratio (SAR).

The average value obtained from the water sample was 166 mg/L which falls within the FAO range of 90-500 mg/l and therefore makes the water suitable that is no threat of irrigation problem.

4.3.7 Magnesium

Soils containing high levels of exchangeable magnesium are often thought to be troubled with soil infiltration problems. The role of magnesium in causing or partly causing these problems is not well documented but researchers from several irrigated areas have studied the problem. At present there is reasonably good agreement that magnesium acts on soils in a way which is more like calcium than sodium. Average value of 5 mg/L is within the FAO recommended limit. Hence, the sample of water is suitable for irrigation of the crop.

4.3.8 Dissolved Oxygen

This is oxygen that is dissolved in water through diffusion from the surrounding air. For plant to survive, dissolved oxygen below 4ppm is considered too low and bad for organisms living in the water (FAO, 1994). Average value of 3.55 ppm is on the low side when compare with recommended limit, low dissolved oxygen in wastewater is an indication that the bacteria concentration is high and when used for irrigation, portends danger to crops and eventually consumers of the crops.

4.3.9 Sodium

Sodium and chloride levels are used to define the type of salts contributing to the electrical conductivity of the water, Electrical conductivity measure the presence of all dissolved salts. If the electrical conductivity reading is elevated, the presence of sodium and chloride indicates that the water source is brackish (salty). Average value of 31.5 mg/L falls within 0-40 mg/L FAO (1994) recommended limit which makes the sample of wastewater suitable for crop growth.

Table 4.2: Particle size distribution and Modified Textural Composition of the Site

Soil	Particle size distribution (%)	Modified textural composition (%)
Gravel	18	-
Sand	45	61.80
Silt	22	26.78
Clay	8	11.11

Based on the United States Department of Agriculture textural classification on soil triangle, the soil was found to be sandy loam soil.

Table 4.3: Results of chemical properties of the Soil

Parameters	Unit	SBI	WWIS	PWIS
pH		1.68	5.40	5.68
Organic carbon	%	0.64	0.46	0.66
Organic matter	%	4.81	3.38	4.81
Total nitrogen	%	0.01	0.089	0.098
Phosphorus	ppm	4.10	3.80	4.20
Sodium (Na)	$Cmolkg^{-1}$	6.10	0.48	0.62
Potassium (K)	$Cmolkg^{-1}$	0.33	0.44	0.34
Magnesium (Mg)	$Cmolkg^{-1}$	10.93	6.85	10.95
EA	$Cmolkg^{-1}$	0.61	0.83	0.63
CEC	$Cmolkg^{-1}$	12.53	8.60	12.54
Bulk density	g/kg	1.40	1.55	1.40

SBI – Soils Before Irrigation
WWIS – Waste Water Irrigated Soil
PWIS – Potable Water Irrigated Soil
EA-Exchangeable Cations
CEC-Cation Exchan Capacity

4.4 Discussions of Soil Samples Analysis

4.4.1 Bulk Density of Soil

The bulk density by definition is the weight per unit volume of oven dry soil. It varies with structural conditions of the soil, particularly in relation to packing. The standard recommended range of bulk density for most soils is 1.0-1.7 g/cm^3 (Ibitoye, 2008). The average value of bulk density obtained from the sample of soil before irrigation was 1.4 g/kg and that of waste water irrigated soil (after irrigation) was 1.55 g/kg. The values fall within recommended range which implies that the soil is in good condition for crop growth and this may be attributed to the location of the soil (River banks)

4.4.2 pH

pH is a unit that describe the degree of acidity or alkalinity of a solution or substance. It is a measure of the active acidity or hydrogen (H^+) of the sample solution. pH is also the negative logarithm of the hydrogen ion concentration. Plant growth may be correlated with hydrogen ion concentration in the soil and living tissues depends on pH. Sample with pH between 0-7 is said to be acidic, pH 7 is neutral, while pH between 7-14 is alkaline.

The average values obtained for soil sample before irrigation and waste water irrigated soil (after irrigation) were 1.68 and 5.40 respectively. These values imply that the soil before irrigation is more acidic than waste water irrigated soil. Therefore, application of wastewater has reduced the acidity of the soil which makes it more suitable for crop growth, because the acidity of the soil should not be too high for effective soil activities (Ibitoye, 2008).

4.4.3 Organic Matter

Carbon is the major element of soil organic matter that is readily measure quantitatively. Hence, estimates of organic matter based on organic-carbon. This usually include; fresh plant and animal residues, capable of rapid decomposition and simultaneous release of nutrient elements, humus, which represents the vast bulk of decayed organic matter, having absorption capacity for cations and capable of improving soil structure and inert forms of elemental- C, such as charcoal, coal or graphite, which are occasionally present in appreciable quantities. Soil organic matter sustains the life of the soil, which are dependent on the quantity of organic matter elements, humus, which represents the vast bulk of decayed organic matter, having absorption capacity for cations and capable of improving soil structure and inert forms of elemental- C, such as charcoal, coal or graphite, which are occasionally present in appreciable quantities. Soil organic matter sustains the life of the soil, which are dependent on the quantity of organic matter present. The values obtained for soil sample before irrigation and after irrigation were 4.81% and 3.38% respectively. This implies that application of wastewater reduces the level of organic matter in a soil sample, which means reduction in sustainability of the soil for crop growth and this may leads to impaired growth of the crop since organic matter play a prominent role in crop production.

Table 4.4 Average length of stem and leaves for the four weeks of growth

Week	Length of	Stems (cm)	Length of	Leaves (cm
	Plot A_1	Plot A_2	Plot B_1	Plot B_2
First	2	1.0	1	-
Second	10	7.5	4.0	2.5
Third	21.1	18.2	6.8	6.0
Fourth	30.0	25.5	8.5	6.8

A_1&B_1 represent average length of stems and leaves of wastewater irrigated plot respectively

A2&B2 represent average length of stems and leaves of control plot respectively.

In the above table, crops grown on the wastewater irrigated plot have the highest length of stems and leaves, this may be due to the nutritive value of wastewater which sometimes serve same purpose as chemical fertilizer. These variations in height of stems and length of leaves were attributed to source of irrigation water applied (wastewater and clean water).

4.5 Leaf Area Index (LAI)

Leaf Area Index (LAI) is one of the most important crop parameters in photosynthesis driving crop growth simulation model and canopy evapotranspiration. Simulation model, while air temperature and radiation are the important climate factors affecting crop leaf growth (Yong Sheng, 2008).

Table 4.5 Leaf Area Index and the Average Breadth for the four weeks

Week	Leaf Area Index	Average Breadth (cm)
First	0.0000	0.8
Second	0.0001	1.2
Third	0.0002	2.5
Fourth	0.0005	3.9

At the end of the experiment, the vegetables were harvested and weighed, the result is in Table 4.6 below.

Table 4.6: Average Weight of harvested vegetables

Water Sample	Weight of harvested vegetables (kg)	Cropped Area (m^2)	Crop yield (kg/m^2)
A	1.20	0.3237	3.7071
B	0.36	0.3237	1.1121

A and B represent samples of wastewater and clean water respectively

Table 4.5 above shows the vegetables of water sample A (wastewater) have higher weight (1.20 kg) when compare with that of control (0.36 kg) and this can also be attributed to difference in composition of the two samples of the irrigation water. This confirms that different water qualities have different elements which play prominent roles in the process of plant growth.

Physical observations were also used in the determination of the effects of the sample of wastewater on the crop growth, and these are shown below with different plates taken during the experiment.

Plate 2. Showing the length of stems and leaves in the first week of the Experiment

Plate 3. Showing the length of stems and leaves in the second week of the Experiment

Plate 4. Showing the length of stems and leaves in the third week of the Experiment

Plate 5. Showing the length of stems and leaves in the forth week of the Experiment

Table 4.2 Laboratory Determinations Needed to Evaluate Common Irrigation Water Quality Problems

Water parameters	Unit	Range in irrigation water
Electrical conductivity	ds/m	0 – 3
Total dissolved solid	mg/L	0 – 2000
Calcium	mg/L	0 – 20
Magnesium	mg/L	0 – 5
Sodium	mg/L	0 – 40
Carbonate	mg/L	0 – 1
Bicarbonate	mg/L	0 – 10
Chlorine	mg/L	0 – 30
Sulphate	mg/L	0 – 20
Nitrate	mg/L	0 – 10
Ammonium	mg/L	0 – 5
Phosphate	mg/L	0 – 2
Potassium	mg/L	0 – 2
Boron	mg/L	0 – 2
pH	1 – 14	6.0 – 8.5
Sodium adsorption ratio	mg/L	0 – 15

Source: FAO, 1994

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

From the analysis carried out in this work, it has been proven that wastewater is a potential alternative for the ever expensive chemical fertilizer because of its nutritive values that serve same purposes as conventional fertilizer, but farmers especially the local ones need to be sensitized and enlightened on how wastewater can be properly and safely used for irrigation purposes because some of its constituents are higher and some are lower in value than the recommended standard and this portends a danger to the crops and even the consumers of the crops. Adequate treatment has been necessitated with variation in values of its constituents like chloride, magnesium and others that are on the high side when compare with FAO (1992) recommended limit (termed the water hard).

The pH value, potassium content, bicarbonate content and some others fall within the FAO recommended limit which shows the suitability of water sample for irrigation. Nitrogen and Calcium contents of the water sample were above the FAO recommended range and these should necessitate the treatment of the wastewater to avoid any threat that might be portend.

5.2 Recommendations

More research should be carried out on this work especially the manner in which the consumers of the affected crops can be affected and also the effects of concentration of heavy metals in the wastewater as they are likely to contribute effectively to accuracy of the result and a proper means should be device to reduce the effects of the heavy metals. I also want to consider it necessary to recommend that a better way of conveying the wastewater from the streams to the farm should be device (like use of generator pumps) for convenience on the part of the farmers.

REFERENCES

Abubakar Salihu (2008), Possible impacts of wastewater reuse in soje irrigation scheme kpakungu, Minna. (unpublished) pp. 38 - 41

Ajibola Owolabi (2005), Effect of various irrigation water qualities on production of (Ammarantus cruentus) vegetable. pp. 47 - 52

A.A. Ibitoye Laboratory manual on basic soil analysis., (2008).

Biological and Agricutural Engineering (BAE) (2002), Research and extension topics outline of R. O Evan Cooperations. J.W. Gillian (son Science). J.C barber (BAE), P.W waterman (BAE) pp. 56 -59

Bhalia S.C (2005), Environmental pollution and control in chemical process industries 2nd edition, Khanna. Pp. 17 ⍰ 172

Drakatos PA et al. (2002), Antogonistic action of Fe and Mn in mediterranean type plants irrigated with wastewater effluensfollowing biological treatment international journal of environm ental studies 59(1): 125 ⍰ 132.

Drakatos PA, Kalavrouziotis Ik, Drakatus SP (2000), Synergism of Cu and Zn in the plants irrigated via processed liquid wastewater journal of land contamination and reclaination, 8(3): 20 1 ⍰ 207.

FA0, 2004, Quality control of wastewater for irrigation crop production.(water report journal.) pp. 1 12 - 16

Joe Tabor, 27 August 201 (last revised), URL:http//cals.arizona.edus/OALS/soils/Composition html.
Site created and mailtained by the office of Anid lands efidies (unpublished) pp. 12 - 18

Kalavrouziotis Ik, Drakatos PA (2002). Irrigation of certain Mediterranean plants with heavy metal. International Journal of Environment and pollution. 18(3): 294 ⍰ 300.

Mangala Rai, S. Mauria (2006). Handbook of Agriculture, Indian council of agricultural research Pp. 389 - 391

Mohamed Abubakar 2007, Bacteriological and physion-chemical Qualitation Analysis of wastewat er in six-geopolitical zone in Nigeria (unpublished)

Pescod MB (1992), Wastewater treatment and use in agriculture. Roe food and agriculture organiza tion of the united nation (FAO irrigation and Drainage page 47).

Smith, RJ. Raine, SR. and Minkovich 2005 (smithetd 2005), Irrigation application efficiency and deep drainage potential under surface irrigated cotton (Agricultural Water Management) pp. 209 - 216

Stirzaker, RJ. (2003) when to turn the water off scheduling micro-irrigation with a wetting front det ector irrigation science (Journal). pp. 78 - 85

Tanji KK, Kielen NC (2002), Agriculture drainage water management in arid and semi ⍰⍰arid area s. Rome, food and agriculture organization of the united kingdom (FAO irrigation and Drainage peper G).

Ying Yong sheng, Tai xne Bco (2008) Oct; 19(10) 2277.83