EFFECT OF USE OF WASTEWATER FOR IRRIGATION ON THE HYDRAULIC PROPERTIES OF SOIL

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MATRIC No. 2004/18397EA

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FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA.

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BEING A FINAL YEAR PROJECT REPORT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B. ENG) DEGREE IN AGRICULTURAL AND BIORESOURCES ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE

FEBRUARY, 2010

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 Information derived from personal communications, published and unpublished work were duly referenced in the text.

Odinachi-Okemiri, Chinyere Kehinde

17 - 02 - 2010
Date

CERTIFICATION

This project entitled "Effect of Use of Wastewater for Irrigation on the Hydraulic Properties of Soil" by Odinachi-Okemiri, Chinyere Kehinde, 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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Engr. Dr. A.A Balami HOD, Agricultural and Bioresources Engineering.	Date
Engr. Prof. G.O. Chukwuma	10-02-10
External Examiner	Date

DEDICATION

This work is dedicated to my family who have stood by me throughout these years and have always made me believe in myself.

ACKNOWLEDGEMENTS

My sincere gratitude goes first to the Almighty God for His gift of life, infinite mercies, amazing grace and the special privilege to complete my Bachelor degree programme in Engineering.

My unreserved appreciation goes to my project supervisor Engr. Mrs. H.I Mustapha whose advice and understanding ensured that this project was a success.

I would like to acknowledge my lecturers, Mr. P.A Adeoye, Mr. Muhammad Sadeeq, Dr. B.A Alabadan, Dr. Mrs. Z.D Osunde and the entire academic staff of Agricultural and Bioresources Engineering for their contribution and support.

I would also like to appreciate the senior staff and the laboratory technologists of the department of Agricultural and Bioresources Engineering for their assistance and the University at large for the opportunity granted me for learning.

My special thanks go to the best parents in the world, Deacon and Deaconess Odinachi Okemiri for their moral, spiritual and financial support especially at this stage of my life.

I would also like to acknowledge my wonderful brothers and sisters; Uzo, Ody, Ike, Ihuoma and my twin sister Chinwe for their love, prayers and belief in me.

My deepest appreciation goes to Ohiorenua Musa, for his support and sacrifices, God bless you.

Finally, I will like to appreciate my friends and course mates in this University. It has been a blessing knowing you all.

ABSTRACT

This study was carried out to evaluate the hydraulic properties of soil and to analyze the effects of use of wastewater on the hydraulic properties of the receiving soil from Soje Kpankungu, Minna. The area of land was divided into four plots, plots A, B, C and D. Two of the plots were irrigated with clean water while the other two were irrigated with wastewater that derives its source from Minna township. The soil samples were tested for their hydraulic, physical and chemical properties while the wastewater was analyzed for its physical, chemical and biological properties. The results revealed a positive effect on saturated hydraulic conductivity and infiltration capacity and a negative effect on soil porosity and permeability. The positive effect could be attributed to an increase in sand and relatively low clay content and lower organic matter content in the soil and due to the positive effect of the pH, temperature and sodium concentration of the wastewater with average values of 7.56, 28.4°C and 31.5mg/l respectively which is within the limit of the WHO standard of 6.5 – 8.15, 20°C – 30°C and 200mg/l respectively of pH, temperature and sodium concentration. The negative effect could be attributed to the breaking of aggregates and filling of some of soil voids by fine particles suspended in the wastewater and could also be related to the turbidity, conductivity and biological oxygen demand of the wastewater with average values of 19.79NTU, 619µs/cm and 16mg/l respectively in comparison with WHO standard for irrigation water of 5 NTU, 1.5µs/cm and < 6mg/l respectively which was above the limit.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the study

Wastewater irrigation is being practiced in many countries around the world because of the substantial benefits accruing to communities as a result of nutrient-rich untreated sewage. These effluents have special significance for developing countries with arid and semi-arid climates and limited water resources. Land application of wastewater and sludge provides nutrients for crop growth as well as organic matter for soil conditioning and it is often the most economic means of wastewater and sludge disposal. (Arar, in press), Rapid population growth, poor water management, not enough wastewater treatment plants and inappropriate pricing policies all contribute to the problem of its reuse. Continuous increase in the demand for water forces water agencies to look for alternative water sources. Especially in arid areas the future demands for water cannot be met through traditional water resources such as surface and ground water. In order to handle increased water demand, wastewater has to be reused. RIAL (2005). However, effluent use for irrigation will conserve valuable water resources and increase crop production. Land application of wastewater also undergoes natural physico-chemical and biological treatments in the soil matrix which provide not only a highly effective low-cost alternative to conventional treatment but also an ecologically balanced and environmentally compatible system of wastewater management. As a result, small farmers prefer wastewater because of its high nutrient content which reduces or even eliminates the need for expensive chemical fertilizers, Scott et al. (2002).

Wastewater is any water that has been adversely affected in quality by anthropogenic influence. It comprises liquid waste discharged by domestic residences, commercial properties, industry, and/or agriculture and can encompass a wide range of potential contaminants and concentrations. In the most common usage, it refers to the municipal wastewater that contains a broad spectrum of contaminants resulting from the mixing of wastewaters from different sources. (Wikipedia, 2009). Furthermore, wastewater can be said to be the liquid and water-carried industrial or domestic wastes from dwellings, commercial buildings, industrial facilities, and institutions, together with any groundwater, surface water, and storm water that may be present, whether treated or untreated, (http;//www.ci.mankato.mn). In an effort to integrate reclaimed water resources in irrigation, the concern for human health and the environment are the most important constraints in the reuse of wastewater. However, close monitoring of the effects can help to improve the performance of wastewater reuse for irrigation. Modification of soil due to the irrigation with treated wastewater mainly depends on; type of wastewater, type of treatment, type of irrigation and type of soil, Feenstra et al. (2000).

Soil constitutes the fundamental building block of all agricultural pursuits. Soil hydraulic characteristics, especially hydraulic conductivity and soil water holding capacity, are important to the design and operation of irrigated agriculture systems. The performance of irrigation systems and practices depends highly on these soil hydraulic properties. Information on soil hydraulic properties is also useful for irrigation scheduling and management including when, how much and at what rate water should be applied. In addition, soil hydraulic properties are often critical input parameters to irrigation and water management models. Information on soil hydraulic properties is required to assist in the siting and management of existing and proposed irrigation developments, appropriate restructuring of irrigation delivery system infrastructure, the targeting of irrigation-related incentive schemes, and regulatory controls on water use. Mehta and Wang (2004).

By definition, soil is the loose material that covers the land surface of the earth and supports the growth of plants. In general, soil is an unconsolidated or loose, combination of inorganic and organic materials. The inorganic components of soil are principally the product of rocks and minerals that have been gradually broken down by weathering, chemical action and other natural processes. The organic materials are composed of debris from plants and from the decomposition of the many tiny life forms that inhabit the soil. Microsoft (R) Encarta (R) (2009). Soil has various characteristics based on soil formation, soil profile, soil organic matter, soil texture, soil structure, porosity and bulk density. In estimating soil hydraulic characteristics, soil hydraulic parameters are evaluated such as the saturated hydraulic conductivity (K), field capacity, soil water holding capacity, permanent wilting point (PWP), infiltration capacity and porosity, Robert et al. (2007).

Agriculture is the major user of water and careful consideration must be given to possible long term effects on soil hydraulic properties by the use of wastewater as a common practice for irrigation.

1.2 Objectives of the study

1. To evaluate the hydraulic properties of soil.
2. To compare the use of treated water and wastewater and its effects on the hydraulic properties of soil.

1.3 Statement of Problem

The Wastewater contains impurities which have long-term effect on soils and plants from salinity, sodicity, nutrients and trace elements that occur normally. The irrigation of soil with this type of water can have effect on soil chemical, physical and biological parameters as mineral macro and micro nutrient contents, soil PH, buffer capacity, cation exchange capacity, infiltration capacity. Doerge, (1999).

The major problems associated with the use of wastewater for irrigation include;

1. The health risk and environmental damage caused by reuse of wastewater.

2. Build up of chemical pollutants in the soil.

1.4 Justification

Treating dirty water, whether it comes from sewage lines or a chemically polluted lake, costs a relative fortune. Sometimes farmers use water from rivers polluted with sewage or runoff from livestock farms, industry and other contaminated sources to irrigate their cropland. This allows bacteria make it into the harvested crops, and people and animals that live off this produce can become ill. When this produce is exported, the problem can spread. If not properly monitored wastewater reuse affects the fertility of soils and could reduce the quality of produce on agricultural lands. However wastewater irrigation is not a rare occurrence and neither is it all bad. This project is of utmost importance to the society and environment because it explores ways of improving the performance of wastewater reuse for irrigation on the hydraulic properties of soil.

1.5 Scope of Study

The project work is carried out based on estimate of using wastewater for irrigation and evaluating its effects on the hydraulic properties of soil in Soje, Kpakungu Minna which is located on the latitude of 9°35' North and 6°33' East in Niger State. The area of the site being 3.6m × 2.4m has a vegetation that is continuously wet as a result of the farming activities taking place in the area. The soil class of the top soil (0-15) cm is sandy loam.

In the cause of this study, the properties of wastewater are analyzed and its effects on the hydraulic properties of soil are evaluated in comparison with the use of clean water for irrigation. This resulted in the recommendation of field management practices in wastewater irrigation

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Wastewater

The term wastewater is defined according to the Food and Agriculture Organization (FAO) of the United Nations (1991) as "the spent or used water of a community or industry which contains dissolved and suspended matter". About 99% of wastewater is water and only 1% is solid waste (FAO, 1991). Wastewater can be utilized in a multitude of applications like irrigation. Several classes of wastewater can be reclaimed for agricultural use. The limiting factors to this process, aside from economics of competing alternatives, rest in the actual or potential contamination by toxic, non-degradable chemicals and in the increase in dissolved organic salts. Wastewater contains physical impurities such as sediments, which are harmless to agriculture and may even help to maintain the fertility of the soil depending on the content. The chemical impurities in wastewater, however, can be harmful when present above certain fairly well defined limit. Wastewater possesses different biological, physical and chemical effects on the environment. These effects mainly results from its physical, chemical and biological qualities and depend on the origin of the wastewater. (Gunnerson *et al.,* 1994)

2.1.1 Previous Reports in the Literature

There have been various reported observations on the effect of wastewater reuse for irrigation on the hydraulic properties of soil. Such reports that have been encountered are presented thus;

In 2003, Tamimi carried out a study on 'wastewater characterization and the reuse of recycled effluent in irrigating agricultural crops'. He reported that effluent contains high amounts of dissolved solid concentration and other constituents that affect soil, crop and the environment. To avoid the negative effect, he stated that proper irrigation management systems are required to prevent soil deterioration and reduction in yield. The author discussed the procedure and methods used for characterization of wastewater, the different parameters used to determine the quality of recycled water and the effects of recycled effluent on soil, crop and the environment. He concludes that the continuous reuse of wastewater in agriculture can have devastating results on the soil, environment and public health. However, appropriate data collection, analysis, designs, testing, evaluation then implementation of the best suitable system is the proper course of action that is needed to be taken when considering such a problem.

Bello (2008) in 'the effect of laundry wastewater on soils hydraulic properties' aimed at estimating and studying the effect of laundry wastewater on hydraulic properties of the receiving soil. He carried out analysis of the wastewater by subjecting them to physical, chemical and biological test. He stated that surfactants in laundry detergents have a greater negative impact on the soils hydraulic conductivity. The author concluded that advance treatment of the effluent using ultraviolent radiation method should be introduced into the system in order to improve the quality of the effluent that is being discharged into the flowing stream.

In 2008, Sheidu described an investigation on the 'effect of wastewater from carwash on soil hydraulic properties'. The author investigated the effect of wastewater from carwash on soil hydraulic properties and compared the result with the FAO standard for irrigation water in other to know the level of contamination. He discovered that the values gotten from the analysis of the wastewater from carwash are above the limit of the FAO standards. The pH of the wastewater was 8.72 which are slightly higher than the FAO standard of 6.5-8.5 for irrigation water. The electrical conductivity and the sodium (Na) content of the wastewater were 513×10^{-6}µs/cm and 63mg/l respectively which were also above the FAO standards of > 260×10^{-6}µs/cm and 0.89mg/l respectively. This resulted in a substantial decrease in the hydraulic conductivity of the soil as a result of the high sodium content, higher pH value, high electrical conductivity and high sodium absorption ratio on the soil sodium which is a primary factor in soil destruction. The author concluded that wastewater from carwash is not suitable for irrigation of agricultural lands.

2.1.2 Types of Wastewater

1. Domestic wastewater: - This is wastewater generated from domestic activities such as wastewater from human body waste (urine and faeces) and sewage which is the discharge from kitchen, baths, lavatories etc from public and private buildings.
2. Industrial wastewater: - Wastewater generated from industrial activities such as tanneries, slaughter houses, distilleries, mills, chemical plants etc.
3. Ground water or subsoil water entering sewers through lakes.
4. Storm water which is rainwater from house roads along with surface water.

2.1.3 Constituents of Wastewater

Wastewater is characterized in terms of its physical, chemical and biological compositions.

2.1.3.1 Physical Characteristics: The most important characteristics of wastewater is its total solid content, which is composed of floating matter, settable matter, colloidal matter, and matter in solution. Some of the other important physical characteristics are turbidity, colour, temperature and conductivity.

i. Total solid content: - This is obtained by evaporating a sample of water to dryness and measuring the mass of residue.

ii. Turbidity: - This is a measure of the light-transmitting properties of water. The measurement of turbidity is based on comparison of the intensity of light scattered by a sample to the light scattered by a reference suspension under the same condition. Formalin suspension is used as primary reference standard. Colloidal matter will scatter or absorb light. Its unit of measurement is Nephelometric Turbidity Units. (NTU).

iii. Color: - The color of water determines its condition which is referred to the age of the waste water. Fresh wastewater is usually brownish gray in color.

iv. Temperature: - The temperature of water is important because of its effects on chemical reaction and reaction rates, aquatic life's and the suitability of water for beneficial uses. For example, increase in temperature can cause a change in the species of fish that can exist in the receiving water body.

v. Conductivity: - The electrical conductivity (EC) of water is a measure of the ability of a solution to conduct an electric current. Conductivity increases as the concentration of ions increases because electrical current is transported by ions in solution. It is used to determine the suitability of water for irrigation and is expressed in SI unit as militiamen per meter (mms. /m).

2.1.3.2 Chemical Characteristics: These are quantified in terms of inorganic and organic constituents. The inorganic non-metallic constituents include pH, Chlorides, Alkalinity and phosphorus.

i. pH: - This is defined as hydrogen ion concentration. It is an important quality of both natural waters and wastewaters. The usual means of expressing the hydrogen ion concentration is as pH which is the negative logarithm of hydrogen ion concentration. The concentration range suitable for the existence of most biological life is typically pH 6 to 9. (FAO, 2006).

ii. Chlorides: - Chlorides is a constituent of concern in wastewater as it can impact the final reuse applications of treated wastewater. Chlorides in natural water result from leaching of chlorides-containing rocks and soils with which the water comes in contact from saltwater intrusion. Industrial and domestic wastewaters discharged to surface water are a source of chlorides.

iii. Alkalinity: - In wastewater results from the presence of hydroxides, carbonates and bicarbonates of elements such as calcium, magnesium, sodium, potassium and ammonia. Calcium and magnesium bicarbonates are the most common. Wastewater is normally alkaline, receiving its alkalinity from the water supply. The alkalinity in wastewater helps to resist changes in pH caused by the addition of acids.

iv. Phosphorus: - Phosphorus is essential to the growth of algae and other biological organisms. Because of noxious algae blooms that occur in surface water there is presently much interest in controlling the amount of phosphorus compounds that enter surface waters in domestic and industrial waste discharges and natural run off. The usual forms of phosphorus that are found in aqueous solution include the orthophosphate, polyphosphate and organic phosphate.

Organic compounds are normally composed of a combination of carbon, hydrogen and oxygen, together with nitrogen in some cases. The organic matter in wastewater typically consists of proteins (40-60 percent), carbohydrates (25-50 percent) and fats and oils (8-12 percent). In general the laboratory methods commonly used to measure gross amounts of organic matter (typically greater than 1mg/l) in wastewater include:

i. Biological oxygen demand (BOD): - This is the amount of oxygen used in the biological oxidation of organic matter in a specified time, at a specific temperature, and under specific conditions. Normally 5 days at 20°C unless otherwise stated, (Raymond CL 1984).

ii. Chemical oxygen demand (COD): - This is the amount of oxygen consumed from a chemical oxidant in a specified test, (Raymond 1984).

2.1.3.3 Biological Characteristics: - Most organisms are commonly present in wastewater and surface water but are usually not present in ground water because of the filtering action of the aquifers. The most common microorganisms in water are bacteria, algae, fungi and protozoa.

i. Bacteria: - These are single celled microorganisms. They posses no well defined nucleus and are devoid of chlorophyll. Bacteria produce by binary fission and exhibit almost all possible variations in morphology, from the simple sphere to very elongated, branching threads. Many serious diseases of humans are caused by bacteria, (Staudenmann and Schonborn 1996).

ii. Algae: - They are unicellular and range in size from 5 to 100mm. They use photosynthesis as their primary mode of nutrition. Algae are typically not of health concern, however, certain species may produce endo or exotoxins, which if ingested at high enough concentrations, may be harmful. (Staudenmann and Schonborn 1996).

iii. Protozoa: - These are unicellular, colourless organisms that lack a cell wall. Several protozoans are pathogenic to humans and these are of interest in water treatment, (Frederic and Pontius, 1990).

iv. Fungi: - Fungi are tiny aerobic heterotrophic, protists containing no chlorophyll. They can tolerate drier and more acid conditions than most bacteria. They live in the Earth, Fresh water and sea water. Often they grow so large that they can be seen with the naked eye (mushrooms), (Staudenmann and Schonborn, 1996).

2.1.4 Wastewater Treatment

The methods of treatment in which the application of physical forces predominates are known as unit operations. The methods of treatment in which the contaminates is brought about by chemical or biological reactions are known as unit processes. Unit operations and processes are grouped together to provide various forms or levels of treatment known as preliminary, primary, advance primary and secondary treatment. In preliminary treatment, gross solids such as rags, sticks, floatables and grit that may cause maintenance or operational problems with the treatment operations are removed. In primary treatment, a physical operation usually sedimentation is used to remove the floating and settable materials found in wastewater. In the advanced primary treatment, chemicals are used or added to enhance the removal of suspended solids, and to a lesser extent, dissolved solids. In the secondary treatment, biological and chemical processes are used to remove most of the organic matter, (Crites and Tchobanoglous, 1998).

A list of unit operations and processes used for removal of major constituents found in wastewater is presented in table below

Table 2.1 Unit operations and processes used to remove constituents found in wastewater

CONSTITUENTS	UNIT OPERATION OR PROCESS
Suspended solids	Screening, grit removal, sedimentation, floatation, depth and surface filtration.
Nitrogen	Chemical oxidation, suspended – growth nitrification and denitrification variations, air striping ion exchange
Phosphrous	Chemical treatment, biological phosphorus removal
Colloidal and dissolved solids	Membrane, Chemical treatment, carbon adsorption, ion exchange.
Volatile organic compounds	Air striping, carbon adsorption, advance oxidation
Odors	Chemical scrubbers, carbon adsorption.

Source: Crites and Tchobanglous, 1998.

2.2 History of use of Wastewater

An understanding of the potential for reuse of wastewater to overcome shortage of freshwater existed in Israel. Indeed, relative to its size and means, Israel has devoted more effort to wastewater reuse than any other country. This has been reflected by the highest percentage in the world of wastewater effluents reused for agricultural irrigation and wastewater reuse per capita. Irrigation with sewage and other wastewaters has a long history also in China and India. In the more recent history, the introduction of waterborne sewage collection systems during the 19^{th} century, for discharge of wastewater into surface water bodies led to indirect use of sewage and other wastewaters as unintentional potable water supplies. Such unplanned water reuse coupled with inadequate water and wastewater treatment, resulted in catastrophic epidemics of waterborne diseases during 1840s and 50s. However, when the water supply links with these diseases became clear, engineering solutions were implemented that include the development of alternative water sources using reservoirs and aqueduct systems, relocation of water intakes, and water and wastewater treatment system, (Vigneswaran and Sundaravadivel, 2004)

For the last three decades or so, the benefits of promoting wastewater reuse as a means of supplementing water resources and avoidance of environmental degradation have been recognized by national governments. The value of wastewater is becoming increasingly understood in arid and semi-arid countries and many countries are now looking forward to ways of improving and expanding wastewater reuse practices. Research scientists, aware of both benefits and hazards, are evaluating it as one of the options for future water demands, (Vigneswaran and Sundaravadivel, 2004).

2.2.1 Wastewater use in developing Countries

The supply of water in several cities is limited, and in many cases, water supply is chronically insufficient for the inhabitants. Despite the inadequacy of water supply, the management and conservation of the available water bodies is generally poor. Industrial growth is fast increasing globally and so also is the water demand for industrial productions or processes. This has put more pressure on the limited available water resources.

Many wastewater irrigators are not landowning farmers, but landless people that rent small plots to produce income-generating crops such as vegetables that thrive when watered with nutrient-rich sewage. Stopping or over-regulating these practices could remove the only income many landless people have. Industrial growth and its associated environmental problem such as soil, plant, and air contamination is fast increasing (Fakayode and Onianwa, 2002)

Obviously the short-term benefits of wastewater irrigation could be offset by the health and environmental impacts. The first step is to scientifically evaluate these. Once the actual risks are clear, we can work to reduce them. This means, for example, finding affordable ways of monitoring the presence of harmful contaminants in wastewater, such as heavy metals that can accrue in soil and crops. It means looking at farming practices and crops grown to find ways of minimizing risks of infection for farmers and consumers.

2.2.2 Wastewater use in developed Countries

Driven by rapid urbanization and growing wastewater volumes, wastewater is widely used as a low-cost alternative to conventional irrigation water; it supports livelihoods and generates considerable value in urban and peri-urban agriculture despite the health and environmental risks associated with this practice. Though pervasive, this practice is largely unregulated in low-income countries and the costs and benefits are poorly understood. Rising demands for water to supply agriculture, industry and cities are leading to competition over the allocation of limited water resources. In advanced countries, environmental monitoring agencies are more effective and environmental laws are strictly followed. General environmental quality monitoring is compulsory and the monitoring of the quality of water resources is done on a regular basis (Neal and Robson, 2000). As a result, any abnormal changes in the environmental or water quality can easily be detected and appropriate action taken before the outbreak of epidemics.

Most developed countries have stringent water-quality standards, and they have implemented sophisticated treatment systems to meet them. But a study regarding global farming practices has shown that the water problems affecting the very poor might end up affecting everybody.

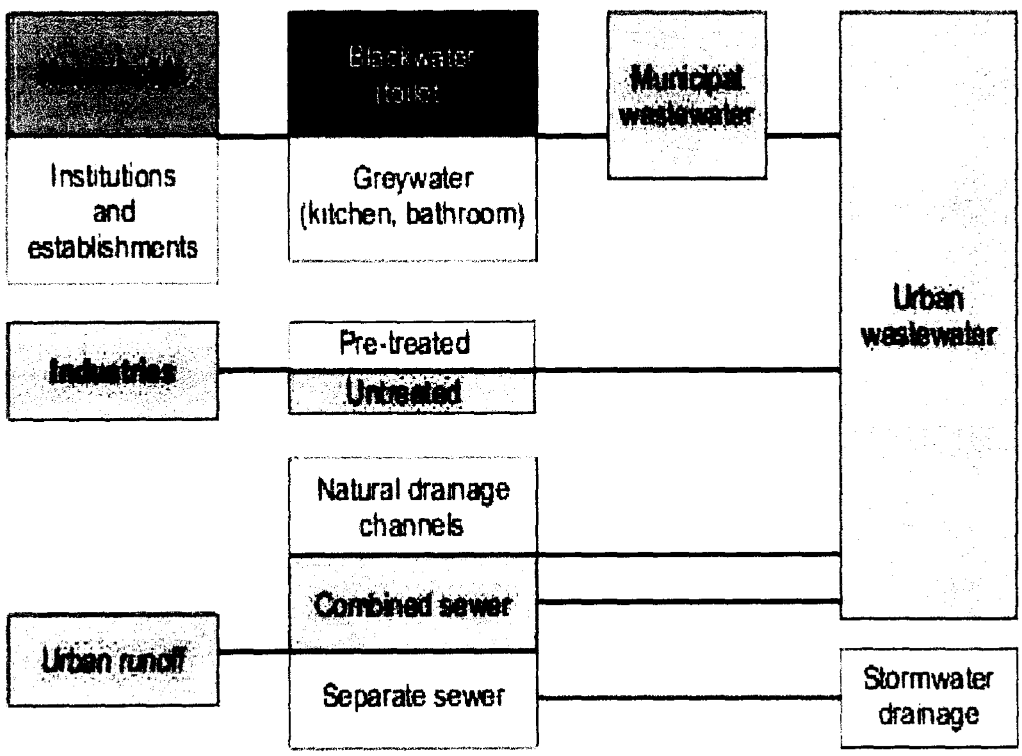

Fig: 2.1. Urban wastewater components (Scott C.A, 2002)

2.3 Irrigation

Irrigation is defined as the artificial application of water to arid land for growing crops, (Sharma, 2007). It is a profession as well as a science. A crop requires certain amount of water at certain fixed intervals throughout its period of growth. Irrigation is not required if this requirement is met with from sufficient rainfall. In tropical countries the first two of the three essential requirements of plant growth, that is, heat and light are available in abundance, but the third, that is, moisture needs to be supplemented frequently by artificial application of water. Thus, irrigation is supplementary to rainfall when it is either deficient or comes irregularly or at unreasonable times. The management of water supply and sanitation is practiced since at least 5000 years ago in Egypt. At that time, it was a challenge how to make use of flash floods. Like today, agriculture was the major water consuming sector and therefore ancient Egyptians focused mostly on irrigation. Ancient Egyptians had only one season in which they cultivated the lands which was enough since the population was much lower than today, (Hussam , 2009).

Irrigation is now successfully employed around the world by many vegetable growers, to assist in the production of high-value crops such as cauliflower, spinach, lettuce, onions, tomatoes, etc. It is used for watering-in the plants, and for maintaining a luxurious growth in times of drought, (Sharma, 2007).

2.3.1 Need for irrigation.

As already mentioned, unless rainfall is sufficient to meet the water requirement of crop throughout their period of growth, need for irrigation water is unavoidable. The necessity for irrigation may thus be summarized as

i. Deficient rainfall: - When rainfall is less than 100cm, irrigation water is essentially required. Rainfall deficiency vis-à-vis irrigation requirement by crop can be briefed as follows.

Rainfall (cm)	Irrigation requirement
100	Rainfall needs to be supplemented by irrigation.
100-50	Rainfall is insufficient. Irrigation is essential.
50-25	Irrigation is essentially required.
Less than 25	No crop can be grown without irrigation.

ii. Non-uniformity of rainfall: - Where rainfall is sufficient but not uniform, concentrated as it usually is in monsoon months, there is acute requirement of irrigation in other periods.

iii. Augmentation of crop yields: - New high yielding varieties of crops have higher water requirement for giving higher yields. Sugarcane and rice have higher requirement of water.

iv. Extracting water requirement: - The high yielding varieties of crops have more extracting requirement of water.

v. Cash crops cultivation: - Cash crops require higher and assured supply of water with frequent waterings for maturity.

vi. Assured water supply: - For successful farming, availability of water is needed quantum and at right times is very essential.

vii. Orchards and gardens: - Fruit trees grown in orchards and gardens have higher requirement of water.

2.3.2 Irrigation Methods

The design, equipment and technique of replenishing the soil water deficit by applying irrigation water* is referred to as irrigation method. The primary objective of any irrigation method is to supply water to soil so that moisture will be readily available at all times for crop growth but without indiscriminately adding to the water table, as well as avoiding influence on soil salinity. The method of applying irrigation water may be classified as surface, subsurface, sprinkler and trickle irrigation.

2.3.2.1 Surface Irrigation

This is by far the most common type of irrigation. In surface irrigation method, since water is applied to the field in varied quantities and at different times, the flow remains unsteady. The method involves diverting a stream of water from the head of a field into furrows or borders, and allowing it to flow downward. Water infiltrates into the soil while transversing the furrow. By subsequent ponding and lateral movement, the soil is restored to its full water holding capacity to a depth that depend on the quantity of water introduced, the duration and the rate of stream flow, the gradient and the soil structure and texture. Highly efficient irrigation can be achieved by an appropriate combination of size of the irrigation stream, uniform application of water, minimum soil erosion, minimum labour requirement, maximum land use, size and shape of field and use of machiner, (Sharma, 2007).

2.3.2.2 Subsurface Irrigation

In sub-surface or sub-irrigation, water is applied beneath the ground by creating and maintaining an artificial water table at some depth, usually 30-75 cm, below the ground surface.

Moisture moves upward towards the land surface through capillary action to meet requirement of the crops in plant root. Water is applied through underground distribution system. Water may be obtained from wells, streams, lakes etc. Water is introduced into soil ptrofile through open ditches, mole drains, or tile drains. Sub surface irrigation requires little field preparation and labour. It entails minimum evaporation loss and surface waste. The irrigation water is essentially required to be of good quality to prevent excessive soil salinity. The flow rate in supply ditches is required to be low to prevent water logging of the field. The use of sub-irrigation is limited because it requires certain soil condition that is the soil is permeable in root zone, underlain by an impervious horizon or high water table, (Sharma, 2007).

2.3.2.3 Sprinkler Irrigation

In sprinkler irrigation system, water is pumped under pressure, carried through high pressure main line and let out through sprinkler nozzles placed at regular intervals on lateral lines to form a gentle rain. The system is designed considering agro-climatic conditions, general land condition, maximum difference in elevation, cropping pattern as different require different amounts of water and different irrigation schedules, cover-crop requirements and their effect on peak water use, requirement and rates, availability of labour, matching pump and power unit, pipe sizes economical to install and operate, water supply source, quantity and quality as essentially clean and debris-free water is required. Considering these factors, the system is so designed that it delivers the right amount of water with optimum rate of application, depth of application and period of application. (Sharma, 2007).

2.3.2.4 Trickle Irrigation

This is also known as drip irrigation. It is the latest developed method of irrigation and was first introduced in Israel. Water is applied at low rate and is often to individual plants. This is accomplished through the use of specially designed emitters or porous tubes. This system provides an opportunity for efficient use of water because of minimum evaporation losses and because irrigation is limited to the root zone due to high cost, their use is generally limited to high value crops. Since the distribution pipes are usually at or near the surface, operation of field equipment is difficult. This method is particularly suited to soils with very low and very high infiltration rates under the conditions of water scarcity and in areas where drainage of excess water is difficult. It is most successful for high income crops because of the relatively high first cost of installation. Both sprinkler and trickle system are well adapted to application of agricultural chemical, such as fertilizer and pesticides with the irrigation water, (Sharma, 2007).

2.3.3 Effects of Irrigation

Irrigation is to agriculture as blood is to the human body. Introduction of irrigation results in changes in vegetation, the fauna and the flora thereby altering the ecology of the command area. These improvements have added advantage of a chain reaction in many spheres which lead to a more prosperous life for the people of the area. Lands which where once barren, infertile with activity with green pastures, verdant forest and teeming population. The human environment too changes as a result thereof. Development of irrigation is alone effective in combating the natural disasters like droughts and the single most promising short and long term means of reducing poverty and generating employment. Irrigation has brought about stability in agricultural production and has made significant contribution in the attainment of self sufficiency in food and hence agricultural independence. All reforms mooted in agriculture will not bear fruit if irrigation facilities are not there to fructify them. Irrigation is an instrument of national integration by developing backward and barren areas and thereby bringing them into national main stream.

2.3.4 Irrigation with Wastewater

Agricultural irrigation has, by far, been the largest reported reuse of wastewater. Four main reasons are responsible for the fast growth of wastewater use for irrigation.

- Reclaimed water serves as an extra source of water available for the rural sector for irrigation. This source is especially important in regions with limited water resources, where the increasing water demand by the urban sector (usually due to a combination of population growth and increasing living standards) is replenished by reducing the water supply to the agricultural sector. The supply of treated wastewater is quantitatively reliable for the farmers, since it depends neither on precipitation nor on the water balance of the whole region.

- Irrigation adds significant polishing treatment to the effluents via break-down of xenobiotic compounds in the soil, evaporation of volatile compounds, pathogens die-off, biological degradation of remaining organic matter, and other processes.

- Surprisingly, disposal of the treated effluents *via* irrigation may be the cheapest disposal alternative (for both construction and operational costs) when compared with disposal *via* discharge to rivers or lakes.

- Disposal of the treated effluents *via* irrigation may also be the alternative with the minimal impact on the environment

Irrigation has the advantage of "closing-the-loop" combination of waste disposal and water supply. Irrigation reuse is also more advantageous, because of the possibility of decreasing the level of purification, and hence the savings in treatment costs, thanks to the role of soil and crops as biological treatment facilities. However, national policy calls for the gradual replacement of freshwater because of the decision to increase the use of effluent and set up a committee to review existing regulations and to recommend new regulations for effluent use for irrigation or disposal to stream and receiving water.

It is important that the community as a whole should become more involved in the working of reuse system.

2.4 Salinity and Chemical Effect of Wastewater Irrigation

Saline soils contain toxic concentration of salts in root zone. Electrical conductivity is taken as a measure of salts. If the solution extracted from the saturated paste of a soil has an electrical conductivity of more than 4mS/m, the soil is termed as saline. High content in soil results in reduction in yield. In alkali soils exchangeable sodium constitutes more than 15 percent of total exchangeable cations. pH value of these soils is usually more than 8.5, (Motsara and Roy, 2008)

2.4.1 Electrical Conductivity

Electrical conductivity (EC) is the most common measure of soil salinity and is indicative of the ability of an aqueous solution to carry an electric current. Plants are detrimentally affected, both physically and chemically, by excess salts in some soils and by high levels of exchangeable sodium in others. EC is expressed in milliSiemens per meter (mS/m). However, EC measurements also have the potential for estimating variation in some of the soil physical properties in a field where soil salinity is not a problem. There is no clear relationship between electrical conductivity (1:5 soil:water) and total soluble salts due to the different ionic conductivities of the various salts and the influence of the soil particles. Soils with an accumulation of exchangeable sodium are often characterized by poor tilth and low permeability making them unfavorable for plant growth, (Doerge, 1999)

2.4.2 Sodium Absorption Ratio

Sodium adsorption ratio (SAR) is a ratio of the sodium (detrimental element) to the combination of calcium and magnesium (beneficial elements) in relation to known effects on soil dispersibility, (Crosby and Enoggera 2007) It is accepted that the SAR and the electrical conductivity of irrigation water can be assessed for the potential to cause dispersion in a soil. High sodium ions in water affects the permeability of soil and causes infiltration problems. This is because sodium when present in the soil in exchangeable form replaces calcium and magnesium adsorbed on the soil clays and causes dispersion of soil particles. This dispersion results in breakdown of soil aggregates. The soil becomes hard and compact when dry and reduces infiltration rates of water and air into the soil affecting its structure. This problem is also related with several factors such as the salinity rate and type of soil. For example sandy soils may not get damage as easy as other heavier soils when it is irrigated with high SAR water.

SAR is a mathematical relationship, set out the concentration of sodium in relation to calcium and magnesium. The sodium comes from the raw water input, the clothes being washed and the laundry detergent.

$$SAR = \frac{[Na^{+}]}{\sqrt{\frac{1}{2}([Ca^{2+}]+[Mg^{2+}])}} \qquad (2.1)$$

Where [ ]; ion concentration

Na: Sodium

Ca: Calcium,

Mg: Magnesium

Fig 2 below illustrates that the higher the salinity, the higher the SAR index in order to cause infiltration problems. On the other hand the lower the salinity, the greater the risk of infiltration problems independent of the SAR value. Rainfall can reduce the soil salinity and consequently increase the SAR index and reduce water penetration into soils.

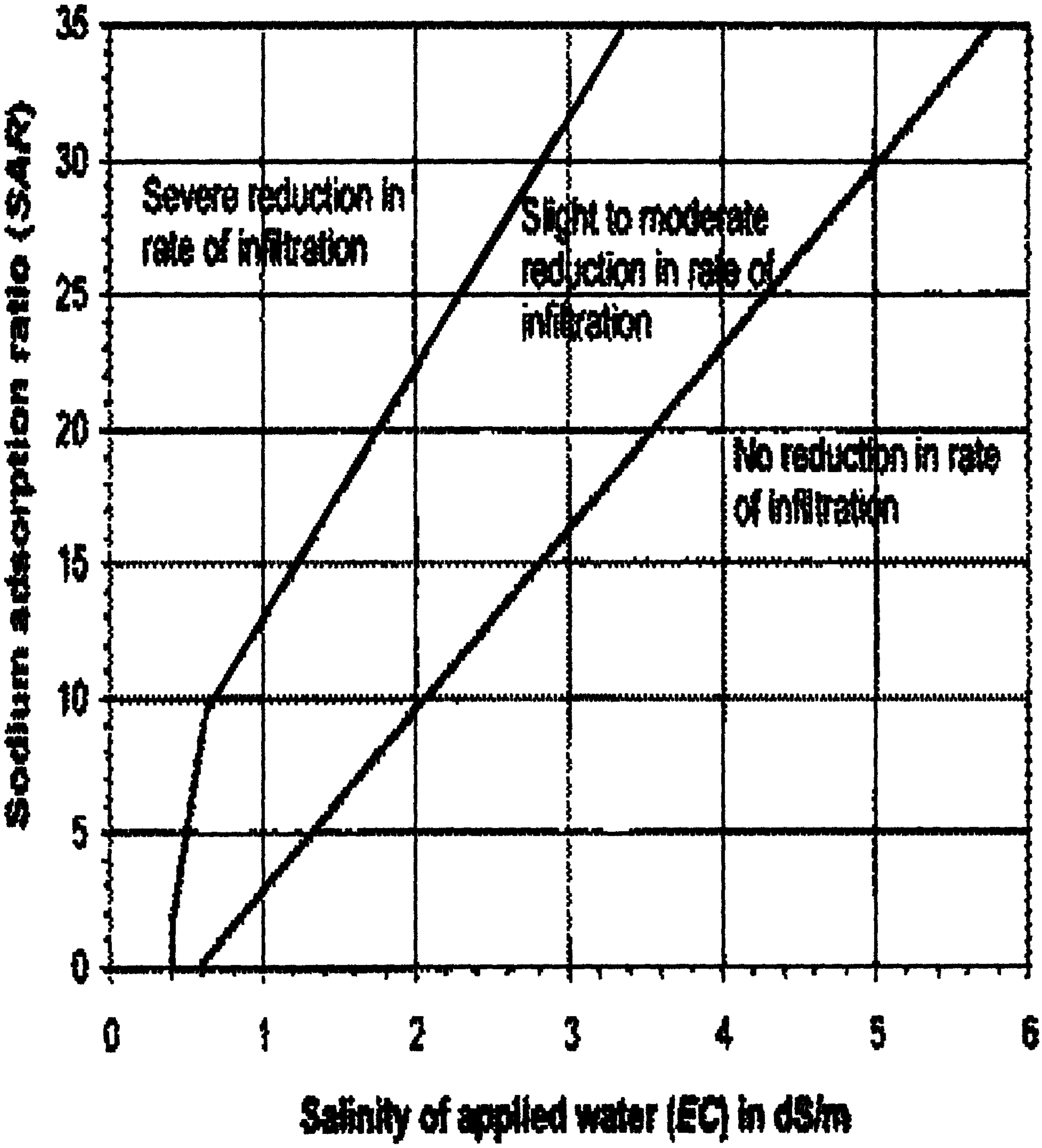

Fig 2.2. Source: Extracted from the Australian Water Quality Guidelines for Fresh & Marine Waters (ANZECC), 1998

2.4.3 Soil Redox Potential

Redox potential is an electrical measurement that shows the tendency of a soil solution to transfer electrons to or from a reference electrode. From this measurement we can estimate whether the soil is aerobic, anaerobic, and whether chemical compounds such as Fe oxides or nitrate have been chemically reduced or are present in their oxidized forms.

2.5 Soil

Soil, from the stand point of agriculture is the upper layer of land surface which supports growth of crops under favorable conditions of temperature and moisture, (Microsoft (R) Encarta (R), 2009) Soil has three essential constituents' namely solid particles, water and air in varying proportions

i. Solid matter: - It mainly consists of inorganic particles derived from the parent rock, mineral material and a small proportion of organic matter.

ii. Air and water: - The solid matter is seldom closely packed to occupy the entire volume of solid mass. There are some open spaces called voids, which are either filled by air or water or both in different proportions. The presence of air and moisture in the soil imparts many important properties to soil. Change in the proportion of moisture and air affects almost all properties of the soil

Besides these three basic components soil contains living organisms like bacteria, fungi, algae, insects and animals which too affect soil structure and plant growth. (Sharma, 2007).

2.5.1 Soil Profile

The soil consists of various layers different in composition and colour known as horizons. The succession of horizons is called profile of the soil. The development of soil as end product of the process of decay and decomposition of rocks proceeds through three recognizable stages. These three stages appear as a series of zones in any section of the soil. These zones are layers approximately parallel to the soil surface and collectively constitute soil profile. The three zones, beginning from the surface downward, are discussed below:

i. Zone A: - It is a zone of leaching and decomposition in which the minerals and organic matter are decomposed and converted into colloids. It is characterized by finely divided particles extending from a few centimeters to 60 cm below the surface. It is the zone in which the grass root, etc., are embedded. It contains humus in most region. The zone has maximum biological activity.

ii. Zone B: - it lies immediately below zone A. It is a zone of decomposition. It extends from a few centimeters to 100 cm thickness. It varies from zone A in colour, structure, clay content and organic matter. Organic matter is low and the main size is rather coarse.

iii. Zone C: - It is layer of unconsolidated material like decomposed rock or freshly deposited alluvium. It is characterized by a coarse grained, rather pebbly texture, making a transition between actual solid rock and the finally decomposed rock. Roots penetrate into this zone. It extends usually up to 2m in thickness, (Sharma, 2007).

2.5.2 Soil Colour

Soil colour is one of the most useful and important characteristics for soil identification. Colour of the soil depends upon its composition, drainage condition, porosity and age.

Concentration of organic matter imparts a grey, black or dark-brown colour to the soil. Diffusion of iron oxides imparts red and yellow colour to the soil. Manganese dioxide and hydrated iron oxides may also contribute red colour. A light grey colour may indicate a very low content of organic matter and iron. Soil colour changes with moisture content and effective drainage.

2.5.3 PH value of Soils

pH value or hydrogen ion concentration is a measure of the intensity of acidity or alkalinity of a soil. Its value ranges from 0 to 14, of which 7 is neutral in the sense of chemical reaction. Below 7 the soil is acidic, above 7 it is alkaline. Soil productivity increases as pH approaches neutrality. Most irrigation soils have pH ranging between 6.0 and 8.5.

2.5.4 Soil Textures

The size of particles comprising the soil determines its texture. The texture of a soil is perhaps its most nearly permanent characteristic, although soil structure can be quickly modified by management. The texture commonly refers to the fineness or coarseness of soil as a whole as to the proportion of the particle groups of different sizes. It is controlled by climate and mineralogical composition of the parent rock. The texture of soils is commonly described by size limits also known as 'particle size'.

The three textural types of soil generally recognized are sandy soils (> 50% sand particles), silt soils (> 50% silt particles) and clayey soils (> 50% clay particles). Loamy soil has mixed particles of sand, silt and clay.

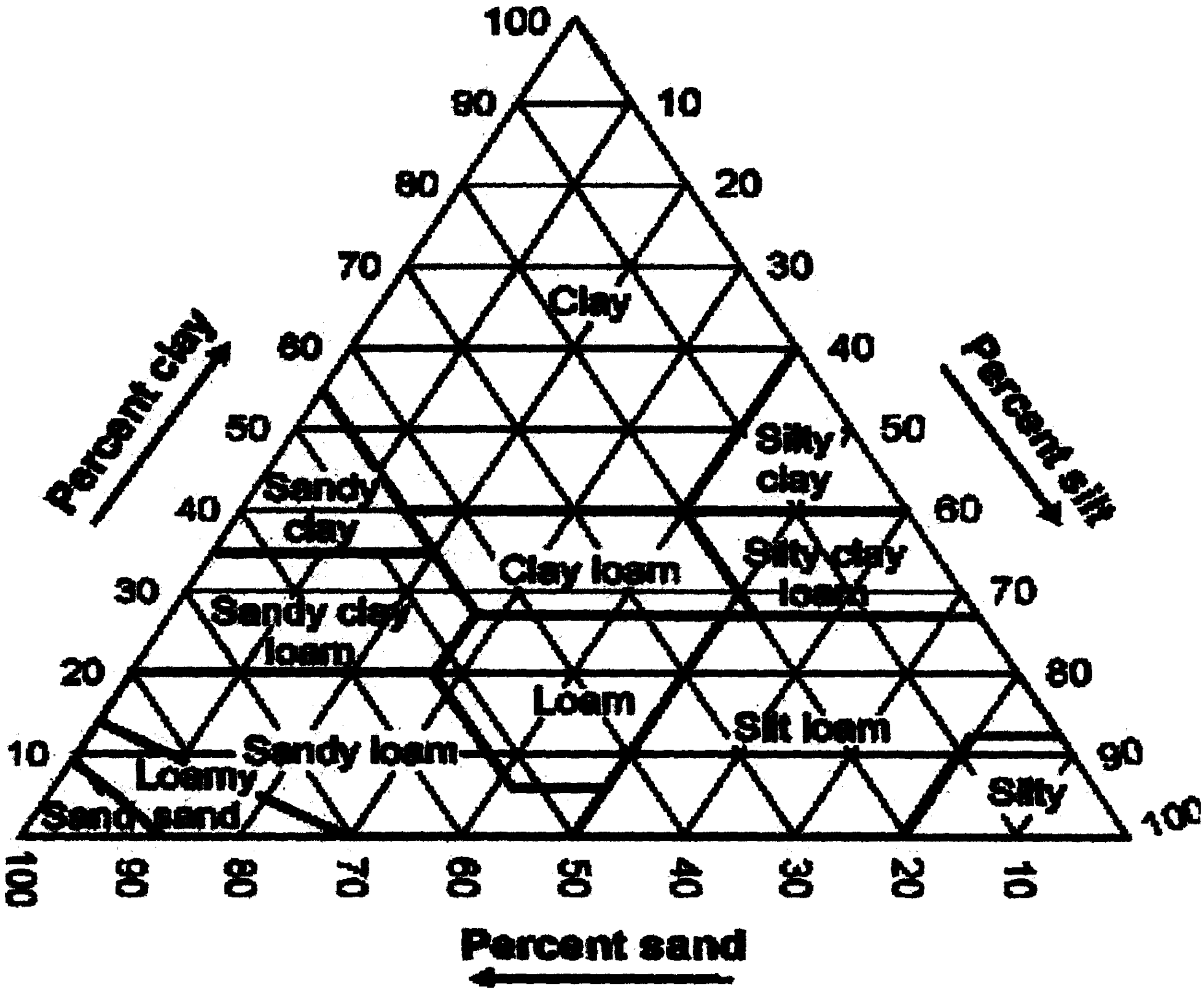

Fig 2.3. Soil texture classes according to proportions of sand silt and clay. Food and Agriculture and Organization (FAO), 1991

2.5.5 Soil Structure

It signifies the arrangement of soil particles, sand, silt, clay, organic matter etc. Unlike texture, soil structure is not permanent but with cultivation practices the top soil becomes granular. The soil structure is important to soil productivity, soil permeability, root growth and soil genesis. The common types of soil structure are granular, prismatic, blocky and massive. Fine grained soils have granular structure in which water entry is rapid with better seed germination and as such are desirable for irrigation as large voids provide space for circulation of air. In prismatic structure the movement of water is mainly vertical and as a result the water supply to the roots is poor. In top soil, massive structure blocks the entry of water, seed germination is difficult and aeration is poor. In blocky top soil, water entry is moderate. From the stand point of agriculture, favorable soil structure is the key to soil fertility, (Sharma, 2007).

2.5.6 Soil Organic Matter

All soils contain living organisms, the majority of these organisms are too small to be seen with naked eyes. When plant residues are turned into the soil they are subjected to rapid bacteria attack and much of the organic matter is lost to the air as carbon dioxide. However a residue of dark color material remains which is called 'humus' or soil organic matter. The amount of organic matter in a soil depends on several factors, the most important being the supply of air. When aeration is restricted due to poor drainage, the breakdown of plants remain by bacteria and other soil organisms is inhibited. So wet soils are normally rich in organic matter and well aerated soil contains much less, (Sharma, 2007).

2.5.7 Soil Moisture Content

This is the ratio of the volume of contained water in the soil compared with the entire soil volume. When a soil is fully saturated, water will drain easily into the underlying unsaturated rock. When such drainage stops, the soil still retains capillary moisture and is said to contain its field capacity moisture content. Further drying of the soil, for example by evaporation creates a soil – moisture deficit, which is the amount of water that must be added to the soil to restore it to field capacity measured as a depth of precipitation.

2.5.8 Bulk Density

It is defined as the mass of many particles of the material divided by the total volume they occupy. The total volume includes particle volume, inter-particle void volume and internal pore volume. Bulk density is not an intrinsic property of a material; it can change depending on how the material is handled.

$$\rho = \frac{M_s}{V_t}$$ 2.2, (Sharma, 2007).

The bulk density of soil is inversely related to the porosity of the same soil. The more pore space in a soil the lower the value for bulk density.

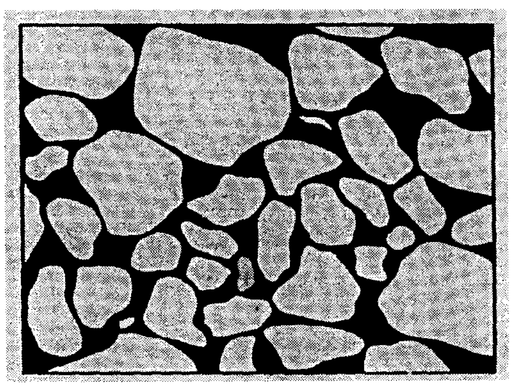

Fig 2.4. Sketch of soil sample to show solid particle and void space distribution. Particles shown in white, voids in black. (Birkeland, 1984)

2.5.9 Depth of Soil

Sufficient depth of soil for the storage of irrigation water and penetration of roots is essential. Shallow soils require frequent irrigation for optimum growth of crops. Deep soils of medium texture and granular structure provide for adequate storage of water and root penetration. It sustains relatively long periods between irrigation. Soils of arid regions are relatively deep compared to humid regions. (Sharma, 2007).

2.6 Hydraulic Properties of Soil

Several soil hydraulic parameters including soil hydraulic conductivity, infiltration capacity, field capacity, porosity, permeability, permanent wilting point, refill point and soil water, are required for various water management activities including selection of and design of irrigation systems, design of drainage systems, supply infrastructure planning and catchment management. The performance of irrigation systems and practices depends highly on these soil hydraulic properties. However, different water management applications require different hydraulic parameters and some hydraulic parameters are required more commonly than others.

2.6.1 Hydraulic Conductivity

Hydraulic conductivity, symbolically represented as K, is a property of vascular plants, soil or rock that describes the ease with which water can move through pore spaces or fractures. It depends on the intrinsic permeability of the material and on the degree of saturation. Saturated hydraulic conductivity, K_{sat} describes water movement through saturated media and is used to define the rate that water moves through the soil pore system when it is saturated. Soils of this region are duplex with a Horizon B (sub soil) underlying a Horizon A (surface soil). The layer in a soil profile that has the lowest hydraulic conductivity is defined as the restricting layer. The restricting layer is located at or below the interface with Horizon B, which can be divided into Horizon B1 and B2 for most soils of the region, (Oosterbaan and Nijland, 1994).

2.6.2 Infiltration Capacity

This is the maximum rate at which soil is capable of absorbing water in a given condition. Alternatively, infiltration is the downward flow of water from the surface into the soil. Infiltration capacity is expressed as cm per hour over an area. Larger the voids, greater is the infiltration capacity. It is related to the saturated hydraulic conductivity of the near-surface soil. Vegetated soils have more infiltration capacity. (Sharma, 2007).

2.6.3 Field Capacity

Field capacity is the amount of water held in the soil after excess gravitational water has drained away and after the rate of downward movement has materially decreased. The field capacity concept is most acceptable for well-drained soils where static or equilibrium state is more easily defined. The concept is difficult to apply to the duplex soils of this region, where the sub-soil often restricts free drainage. The soil water suction values generally used for field capacity approximation range from 5 kPa for coarse-texture soils to 10 kPa for samples that retain their original structure (Marshall, 1992).

2.6.4 Porosity

Porosity is the ratio of the volume of openings (voids) to the total volume of material. Porosity represents the storage capacity of the geologic material. The primary porosity of a sediment or rock consists of the spaces between the grains that make up that material. The more tightly packed the grains are, the lower the porosity. The primary porosity of unconsolidated sediments is determined by the shape of the grains and the range of grain sizes present. In poorly sorted sediments, those with a larger range of grain sizes, the finer grains tend to fill the spaces between the larger grains, resulting in lower porosity. The porosity of some rock is increased through fractures or solution of the material itself. This is known as secondary porosity, (Wikipedia free encyclopedia 2009).

2.6.5 Permeability

It is an important quality of the soil that enables it to transmit water or air. It is defined as the velocity of flow under a unit hydraulic gradient. It depends on presence of minute openings in the soil as also on the size, shape and arrangement of such openings. Sandy soils of coarse texture have large pore spaces and hence high permeability. Clayey soils of fine texture have relatively small pore spaces and hence low permeability. Permeability is affected by water temperature, texture and structure of the soil, (Sharma, 2007).

2.6.6 Permanent Wilting Point

Permanent wilting point is defined as the water content at which the leaves of a growing plant reach a stage of wilting from which they do not recover. Different plants have different values of soil water suction at wilting point. Since the change in water content is small between 800 kPa and 3000 kPa for most soils, a suction of 1500 kPa based on wilting studies with dwarf sunflower is generally taken to be an approximation of permanent wilting point (Reeve and Carter, 1991).

2.6.7 Refill Point

Not all water in the soil is readily available to the plant. Readily available water (RAW) is the volume of water that the plant can readily remove from soil. When all the readily available water has been used, the plants cannot easily extract further water. This stage is referred to as the refill point (RP), and this is generally considered the time to irrigate

2.6.8 Soil Water

Soil water is defined as suspended water in the uppermost belt of soil, of zone of aeration lying near enough to surface to be discharged into the atmosphere by transpiration of plants or by evaporation from the soil. It includes gravitational water, capillary water and hygroscopic water.

i. Gravitational water: - This is the water in the unsaturated zone in excess of hygroscopic and capillary water which moves out of the soil under favorable drainage condition.
ii. Capillary water: - This is the water held by surface tension in the capillary spaces and as a continuous film around the particles, free to move under the influence of capillary forces and available to plants.
iii. Hygroscopic water: - It is the water held in static state with the atmospheric water vapour. Hygroscopic coefficient is the percentage of moisture the dry soil will take up from the saturated atmosphere in order to be in equilibrium with atmospheric saturated water vapour at that particular temperature. Hygroscopic water is not capable of any movement by gravity or capillary forces. (Sharma, 2007).

CHAPTER THREE

3.0 MATERIALS AND METHOD

3.1 Description of Study Area

The Study Area Soje, Kpakungu Minna is located on the latitude of 9°35' North and 6°33' East in Niger State and is under Bosso Local Government Area of the State. The area of the site is 3.6m × 2.4m with a soil class of sandy loam at the top soil (0-15) cm depth (Table 4.2). It has vegetation that is continuously wet as a result of the farming activities taking place in the area. The municipal wastewater derives its source from Minna township. The water flows through an unlined channel and land owners take advantage of its continuous flow for irrigation. The climatic condition of the area; Rain starts in April and ends in October with an average rainfall of 103.3m annually, the average temperature ranges from 22.5°C minimum to 33.6°C maximum annually with an average annual relative humidity of 50.2%, (NIMET Minna). Its climate is influenced mainly by the South West Monsoon winds from the oceans and the dry dusty or harmattan North East winds (air masses) from the Sahara desert.

3.2 Experimental Procedure

The area of land was divided into four plots, A_1, A_2, B_1 and B_2. Plots A_1 and A_2 were irrigated with treated water while plots B_1 and B_2 were irrigated with wastewater for a period of 4 weeks (May – June 2009). The soils samples were taken to the laboratory before and after commencement of the experiment for analysis of their physical, chemical and hydraulic properties at depth 15cm while the water samples were analyzed for their physical. chemical and biological properties. Spinach seeds were sown on each plot using broadcasting method of planting.

3.3 Materials used for the Experiment

There are various materials used for the experiment which range from simple equipments to complex equipments used for the soil and water analysis. Such simple equipments include hoe, shovel, ruler and watering can.

The tools used for the soil analysis include: standard hydrometer, electric stirrer, plunger, cylinders, amyl alcohol and calgon solution for particle size analysis; core sampler, sharpened knife, weighing balance and air circulated oven used for bulk density determination; core cylinder, stop watch and graduated beaker used for saturated hydraulic conductivity measurement; acetic acid, ammonia solution, (NH_3), ammonium acetate, NH_4OAc (pH 7) extracting solution, ethanol washing solution and NaCl extracting solution used for the determination of exchangeable cations;

Tools used for the water analysis include: the pH meter, distilled water, pH meter electrode and 250ml beaker used for pH analysis; turbidity meter used for turbidity test; potassium chromate indicator solution, (K_2CrO_4) and silver nitrate solution, ($AgNO_3$) used for chloride determination; oxalic acid [$C_2H_2O_4$] and sodium hydroxide solution, (NAOH) used for the determination of chemical oxygen demand; conductivity meter used for determination of conductivity of the sample.

3.4 Soil Analysis

3.4.1 Determination of particle size analysis by hydrometer method

Two millimeter (2mm) air dried soil and 50g of the sample was weighed, 100ml of distilled water was added to the sample in a bottle and 5% sodium hexametephosphate solution which serve as a dispersing agent was added. The mixer was placed in a shaker and the shaked content was transferred quantitatively without losing any particle into the sedimentation cylinder, up to 1 liter marked with distilled water. The soil sample was disturbed with the aid of a plunger for proper soil suspension. The hydrometer was immersed into the sample and the stop watch was used to take reading. The temperature of the suspension was also taken by immersing the thermometer into the sample. The 40 seconds reading was also taken to measure the percentage of silt and clay in suspension. A blank sample was also prepared but without soil and the reading also obtained.

3.4.2 Bulk Density Determination

The core method consists of two cylinders filled that the one inside collect the soil sample. The outer one extends above and below the inner to accept a hammer or press at the upper end.

The sampler is driven into the soil surface to fill the sampler but not so far as to compress the soil. Then the sampler is carefully removed along with its contents. The two cylinders are separated with the undisturbed soil retained in the inner cylinder. The soil is trimmed at both ends with a knife. The empty can, W_1 was weighed. The soil was transferred to pre-weighed can weighed W_2 which was oven dried for about 24 hours at 105°C. The volume of the core sampler, $V = \pi r^2 h$ was determined. Bulk density can be calculated from the equation below.

$$\text{Bulk density, } D_b = \frac{W_2 - W_1}{V} \qquad 3.1 \text{ (Ibitoye 2008)}$$

Where $W_2 - W_1$ = weight of oven – dry soil

V = volume of oven – dry soil

3.4.3 Measurement of Moisture Content

A clean and labeled moisture can that had been oven – dried was weighed, W_1. Enough soil sample was added into the mixture can and weighed, W_2. The moisture can was transferred into a thermo-setting oven of about 110°C for 24 hours or to a constant weight. The moisture was removed and allowed to cool in a desicator for about 1 hour and the oven – dried moisture can containing the soil was weighed, W_3. The percentage moisture content can be determined from the formula below.

$$\text{Percentage moisture content} = \frac{W_2 - W_3}{W_3 - W_1} \times 100 \qquad 3.2 \text{ (Ibitoye 2008)}$$

Where $W_2 - W_3$ = loss in weight

$W_3 - W_1$ = weight of soil after drying

3.4.4 Soil pH Measurement using Soil Testing Kit.

A little quantity of barium – sulphate was put into the test tube provided in the kit closed at one end. The soil which had been sieved through 2mm sieve was added in a little quantity. Distilled water was then added to reach the lower mark and soil indicator was added to reach the upper mark. The upper end was closed with a cork. The mixture was stirred and allowed to stand for about 30 minutes. The pH was determined by carefully comparing the solution with the standard chart.

3.4.5 Determination of Soil Organic Matter

The soil sample was grinded into fine powder. 1g soil sample was weighed out in duplicate and transferred to 250ml conical flask. 10ml of $K_2Cr_2O_7$ was added. H_2SO_4 was then rapidly added and the flask was gently swirled until soil and reagent were mixed. After standing for 30 minutes, 100ml of distilled water was added. 3 - 4 drops of ferroin was also added and then titrated with 0.5M iron (II) ammonium sulphate. A blank titration was made in the same manner but without soil. The reaction, $K_2Cr_2O_7$ oxidizing carbon and the excess $K_2Cr_2O_7$ was titrated with iron (II) solution. The result obtained was recorded.

3.4.6 Exchangeable Cation Determination

The leaching tube was prepared with the correct filter paper and Buchner flask with suction pump. 10g of air dry soil was weighed into the 250ml beaker and 100ml of NH_4OAc was added and shaken for about 1 hour using mechanical shaker. The content in the beaker was transferred to the Buchner flash and filtered with the suction pump. The soil residue was washed by leaching with 100ml 95% ethanol with about 20ml at a time to remove the excess NH_4^+, the leachate is discarded. The soil is leached with 100ml of 1M NaCl into a 100ml volumetric flask. NH_4^+ is then determined in the leachate as a measure of the cation by distillation. .

3.4.7 Soil Hydraulic Conductivity Measurement

Soil sample were collected from two plots at 0 – 15cm depth each using core samplers which were labeled and completely basin filled with water to about 4cm. The experiment was set up by attaching another empty core sampler to the top of the filled samplers with the aid of a cello-tape. Water was slowly introduced into the core cylinder and a constant head was maintained for 1 hour. Water was allowed to drain gradually through the soil sample into the graduated beaker. The volume of the perculate was measured. This was repeated for the samples and the hydraulic conductivity was determined as follows

$$\text{Saturated hydraulic conductivity} = \frac{\text{Volume of water per hour}}{\text{Cross sectional area of the core}} \qquad 3.3 \text{ (Ibitoye 2008)}$$

3.4.8 Porosity Measurement using Core Method

A saturated soil core was weighed, the volume of the core determined and thereafter oven – dried to a constant mass. The total pore space is the volume of the water at soil saturation obtained from its mass. The porosity can be expressed by the following equation.

$$\text{Porosity} = \frac{\text{Total pore volume}}{\text{Bulk soil volume}} \times 100 \qquad 3.4 \text{ (Ibitoye 2008)}$$

$$\text{Where pore volume} = \frac{\text{mass of water loss}}{\text{Density of water}} \qquad 3.5 \text{ (Ibitoye 2008)}$$

3.5 Water Analysis

3.5.1 Determination of Water pH

The pH was determined to know the acidity or alkalinity of the water samples. The Ph was taken using oyster – 10 pH meter. The electrode of the pH meter was washed with distilled water and rinsed with the water sample. It was then inserted into 250ml beaker containing the water sample. The meter was switched on and the pH reading was taken from the digital display.

3.5.2 Measurement of Conductivity

A CMD 800 hydro check conductivity meter was used to determine the conductivity of the effluent sample. Before meaningful and repeatable measurement of conductivity was made, the setting for cell constant K and sample temperature were made for specific conductivity at 25°C or at least known for absolute measurement. To view the cell constant K, μs (micro siemens) was switched on to by key A. Then C + A (hold) – K was displayed. Making measurement, key A was switched on and cell inserted into test solution and then the reading was displayed.

3.5.3 Turbidity Determination

The JMP turbidity meter was placed on a flat and level surface which was calibrated with the recommended standards. The prepared sample was placed and aligned with the meter's index mark. The vial is pushed until it is fully snapped in. The vial is covered with the light shield cap and turned on by pressing the ON key. A value appears after about 12 seconds. This is the turbidity value.

3.5.4 Nitrate Measurement using Cadmium Reduction Method

This method uses commercially available cadmium (cd) granules treated with copper sulphate ($CuSO_4$) and packed in a glass column. The nitrate produced is thus determined by diazotizing with sulfanilamide and coupling with N – (1 – naphthyl) – ethylenediamine dihydrochloride to form a highly coloured azo dye that is measured colorimetrically. The applicable range of this method is 0.01 to 1.0 mg/l. The method is recommended especially for nitrate levels below o.img/l where other methods lack adequate sensitivity

3.5.5 Determination of Chloride

A suitable portion of the sample was diluted to100ml. 3ml $Al(OH)_3$ suspension was added, mixed, left to settle, and then filtered. If sulfate, sulfide or sulfite is present, 1ml H_2O_2 is added and stirred for about 1 minute. 1ml K_2CrO_4 indicator solution is then added and titred with standard $AgNO_3$ titrant to a pinkish yellow end point. It is important to be consistent in end – point recognition.

3.5.6 Dissolved Oxygen (DO) and Biological Oxygen Demand (BOD) Analysis

The DO for the diluted sample was weighed (blank with water only) after 15 minutes of preparation. The dilution of 850ml of clean tap water and 50ml of filtered sample was fed into an incubator bottle. 2ml of concentrated H_2SO_4 was added and shaken until the precipitate dissolved. 100ml of the resulting solution was transferred into a conical flask and allowed to filter with an oil dilution of sodium triosulphate ($Na_2S_2O_3$). Few drops of starch solution were added as an indicator until the mixture became blue in colour. The quantity of $Na_2S_2O_3$ which turned sample colour to colourless (neutralization point) was recorded as the DO in the sample. Biological oxygen demand is expressed as;

$$BOD_5 = \frac{DO_1 - DO_5}{D_1} \qquad 3.8 \text{ (Ibitoye 2008)}$$

Where DO_1 = dissolved oxygen of diluted sample after 15 minutes of preparation

DO_5 = dissolved oxygen of diluted sample after 5 days

D_1 = decimal fraction of dilution water used.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Result of the Soil Analysis

The results of the soil analysis are given in the table below:

Table 4.1 Soil analysis

Parameters	Unit	Soil A_1	Soil A_2	Soil B_1	Soil B_2	Soil A (average)	Soil B (average)
Soil pH		5.64	5.72	5.30	5.50	5.68	5.40
Organic carbon	%	0.82	0.50	0.43	0.53	0.66	0.48
Organic matter	%	4.1	5.5	3.52	3.24	4.8	3.38
Total nitrogen	%	0.105	0.091	0.90	0.88	0.098	0.089
Exchangeable Na	Mol/kg	0.63	0.61	0.50	0.46	0.62	0.48
Exchangeable K	Mol/kg	0.37	0.31	0.41	0.47	0.34	0.44
Exchangeable Mg	Mol/kg	10.96	10.94	6.80	6.90	10.95	6.85
Exchange acidity EA	Mol/kg	0.55	0.71	0.82	0.84	0.63	0.83
Cation Exchange Capacity CEC	Mol/kg	12.53	12.55	8.63	8.57	12.54	8.60

Exchangeable Sodium Percentage ESP	ppm	1.92	1.80	1.87	1.81	1.86	1.84
Bulk density	g/kg	1.54	1.26	1.59	1.51	1.4	1.55
Moisture content	% Vol	13.0	13.2	19.2	18.4	13.1	18.8
Saturated hydraulic conductivity	Cm/hr	11.10	11.22	13.40	13.0	11.16	13.20
Infiltration capacity	Cm/hr	2.53	2.53	4.51	4.53	2.53	4.52
Porosity	%	47.5	46.5	39.82	39.86	47.00	39.84
Permeability	Cm^2 ($\times 10^{-8}$)	26.91	27.11	22.74	21.72	27.01	22.23

Soil A_1 and A_2 = soils irrigated with treated water

Soil B_1 and B_2 = soils irrigated with waste water

Soil A = average values of soils irrigated with treated water

Soil B = average values of soils irrigated with wastewater

4.2 Discussion of RESULT

4.2.1 Soil pH

Soil pH was lower in the soil irrigated with wastewater than the soil irrigated with treated water. The average soil pH decreased from 5.68 to 5.40 which were as a result of the application of wastewater to the soil. The decrease in soil pH from neutral to acidity suggests a decrease in the hydraulic properties of the soil. However to avoid the negative effect, a proper irrigation management system is required to prevent soil deterioration.

4.2.2 Organic Matter

The application of wastewater caused a decrease in the average percentage soil organic matter from 4.8% in the soil irrigated with treated water to 3.38% in the soils irrigated with wastewater. It was observed that the dissolved organic matter in the wastewater had a positive effect on soil hydraulic conductivity. The increase in soil hydraulic conductivity was due to less suspended materials present in the wastewater.

4.2.3 Exchangeable Sodium

The soil irrigated with wastewater exhibited a lower concentration of exchangeable sodium (Na) than the soil irrigated with treated water which have average values of 0.62mol/kg and 0.48mol/kg respectively. The low sodium content reflected the low sodium concentration in the wastewater of 31.5mg/l. The reduction in concentration of exchangeable sodium increased the hydraulic properties of the soil.

4.2.4 Magnesium Content

The average magnesium content for soil irrigated with wastewater was 6.85mol/kg and that irrigated with treated water was 10.95mol/kg. The decrease in magnesium (Mg^{2+}) content reflected the replacement of magnesium with sodium (Na^{+}) and calcium (ca^{2+}) and since calcium has much higher adsorption affinity than magnesium. The reduction in the magnesium content of soil increased the soil hydraulic properties.

4.2.5 Exchangeable Sodium Percentage

The average exchangeable sodium percentage showed a decrease from 1.86ppm to 1.84ppm in the soil irrigated with treated water and the soil irrigated with wastewater respectively. This was due to the regular amendment with calcium (ca) products. The use of this wastewater has a positive effect on infiltration capacity and saturated hydraulic conductivity.

4.2.6 Soil Bulk Density

There was an increase in the average bulk density from the soil irrigated with treated water, 1.4g/kg to the soil irrigated with wastewater, 1.55g/kg. This could be related to the filling of some soil porosity by fine particles. The increase in bulk density caused a decrease in soil porosity. Therefore to ensure the sustainability of using wastewater for irrigation, proper irrigation management systems are required to prevent soil deterioration.

4.2.7 Saturated Hydraulic Conductivity

The application of wastewater caused an increase in the saturated hydraulic conductivity from average values of 11.16cm/hr to 13.20cm/hr in the soils irrigated with treated water and wastewater respectively. This could be a result of increase in sand and relatively low clay content, and lower organic matter content. Conductivity increases with increase in sand and decreases with decrease in clay.

4.2.8 Infiltration Capacity

The infiltration capacity showed an increase from average values of 2.53cm/hr in the soil irrigated with treated water to 4.52cm/hr in the soil irrigated with wastewater. This could be attributed to the soil type, sandy loam. The result of the hydraulic conductivity showed an increase which implies that the infiltration rate will exhibit increase as well since they are both closely related.

4.2.9 Porosity

The wastewater irrigation caused a reduction in the average soil porosity from 47.00 to 39.84. The decrease could be attributed to the breaking of aggregates and the filling of some of soil voids by fine particles suspended in the wastewater which also caused an increase in soil bulk density. To avoid this negative effect, a proper irrigation management system is required to avoid soil deterioration.

4.2.10 Moisture Content

The average moisture content showed an increase in volume from 13.1 to a volume of 18.8. The increase could be attributed to the particle size distribution (Table 4.3). Due to higher clay fraction in the soil irrigated with wastewater it will retain moisture more than the soil irrigated with treated water. The increase in moisture content could also be a result of capillary rise of water since the soil irrigated with wastewater has a higher sand content than the soil irrigated with treated water.

Table 4.2 Result of Particle Size Analysis

Parameters	Unit	Soil A_1	Soil A_2	Soil B_1	Soil B_2	Soil A (average)	Soil B (average)
Sand	%	95.14	95.10	96.13	96.11	95.12	96.12
Silt	%	2.75	2.65	3.61	3.59	2.70	3.60
Clay	%	-2.92	-2.80	0.26	0.30	-2.86	0.28

Table 4.2 shows the result of the particle size analysis of the soils irrigated with treated water, (Soil A) and the soils irrigated with wastewater, (Soil B). The average percentage soil particle compositions of soil A are as follows; 95.12% sand, 2.70% silt and -2.86% clay. This falls into the soil textural triangle (Figure 3.0). The corresponding soil textural class is sandy loam. The average percentage soil particle compositions of soil B are as follows; 96.12% sand, 3.60% silt and 0.28% clay. The corresponding soil textural class is also sandy loam.

Comparing the percentage composition of the soils; the percentage of sand increased from soil A to soil B and as a result, soil B will transmit water than soil A. Due to higher clay fraction in soil B, it will hold water more than soil A.

4.3 Result of the Water Analysis

The results of the water analysis are given in the table below:

Table 4.3 Water analysis

Parameters	Unit	Wastewater A	Wastewater B	Wastewater C	Average Wastewater
pH		7.53	7.21	7.94	7.56
Nitrate	mg/l	182.48	182.40	182.47	182.45
Turbidity	NTU	19.75	19.69	19.93	19.79
Chloride	mg/l	23.98	24.00	23.96	23.98
Temperature	°C	28.1	28.6	28.5	28.4
Biological Oxygen Demand	mg/l	15.4	16.7	15.9	16
Total dissolved solid	mg/l	414.81	414.52	414.86	414.73
Electrical conductivity	µs/cm	619.5	619.1	618.4	619
Magnesium	mg/l	1.0	1.6	0.7	1.1
Calcium	mg/l	40.62	40.38	40.44	40.48
Color	TCU	257	239	242	246
Hardness	mg/l	103	110	105	106
Sodium	mg/l	31.9	31.5	31.1	31.5

4.4 Comparison of the Results of the Average Wastewater Analysis with that of World Health Organization (WHO) Standard for Irrigation.

Table 4.4: Average wastewater and WHO standard

Parameters	Unit	Average Wastewater	WHO Standard
pH		7.56	6.5 – 8.5
Nitrate	mg/l	182.45	50
Turbidity	NTU	19.79	5
Chloride	mg/l	23.98	250
Temperature	°C	28.4	20 – 30
Biological Oxygen Demand	mg/l	16	< 6
Total dissolved solid	mg/l	414.73	1000
Electrical conductivity	µs/cm	619	1.5
Magnesium	mg/l	1.1	200
Calcium	mg/l	40.48	200
Color	TCU	246	15
Hardness	mg/l	106	100
Sodium	mg/l	31.5	200

4.4.1 Temperature

The wastewater analysis showed an average temperature of 28.4°C and in comparison with the WHO standard for irrigation water, it was discovered that it is within the limit of WHO with a range of 20°C – 30°C. The temperature will have a positive effect on chemical reaction and reaction rates and hence improve soil hydraulic properties. The value of the temperature can be as a result of field management practices in wastewater irrigation such as blending of wastewater with other water supplies.

4.4.2 Nitrate

The concentration of nitrate in the wastewater had an average value of 182.45mg/l which in comparison to WHO standard for irrigation water of 50mg/l was above the limit. This would have a negative impact on the hydraulic properties of soil. The higher value of nitrate concentration could be related to the source of the wastewater.

4.4.3 Turbidity

The turbidity of the wastewater was above the limit of WHO standard. In comparison with the WHO value of 5 NTU it had an average value of 19.79 NTU. The higher turbidity value may be related to the source of the wastewater. This would have a negative effect on soil porosity.

4.4.4 pH

The average pH of the wastewater had a value of 7.56 and in comparison with the WHO standard, it was observed that it is within the WHO limit with a range of value 6.5 – 8.15. This has a positive effect on saturated hydraulic conductivity and infiltration capacity. The pH value of the wastewater could be due to field management practices in wastewater irrigation such as alternating treated wastewater with other water sources

4.4.5 Conductivity

The conductivity of the wastewater had an average value of 619µs/cm and in comparison with the WHO standard, it was above the WHO limit of 1.5µs/cm. This has a negative effect on the hydraulic properties of soil. The higher value of conductivity may be related to the increase in ions concentration in the wastewater.

4.4.6 Sodium

The wastewater analysis showed an average sodium concentration of 31.5mg/l. In comparison with WHO standard for irrigation water, it was observed that this was not above the standard of 200mg/l. This had a positive effect on Exchangeable Sodium Percentage (ESP) and hence increased infiltration capacity and saturated hydraulic conductivity. The sodium concentration could be due to field management practices in wastewater irrigation such as blending of wastewater with other water supplies.

4.4.7 Biological Oxygen Demand

The average Biological Oxygen Demand (BOD) of the wastewater had a value of 16mg/l which in comparison with WHO standard for irrigation water was observed to be above the WHO limit of < 6mg/l. This would have a negative effect on the permeability of the soil. The BOD of the wastewater could be related to the source of the water.

4.4.8 Color

The color of the wastewater was above the limit of WHO standard and in comparison with WHO value of 15 TCU it had an average value of 246 TCU. The color of the wastewater is related to the source of the water which acts as a good indicator of water quality problems and would have a negative effect on soil hydraulic properties.

4.4.9 Hardness

The hardness of the wastewater had an average value of 106mg/l and in comparison with the WHO standard for irrigation water, was slightly above the WHO limit of 100mg/l. This has a negative effect on the hydraulic properties of soil. The hardness of the wastewater could be due to the presence of calcium and magnesium salts.

CHAPTER FIVE

5.0 Conclusion and Recommendation

5.1 Conclusion

Based on the result of the soil and water analysis and the comparison with WHO (2006) standard for irrigation water, the effect of use of wastewater for irrigation had both a positive and negative impact on the hydraulic properties of soil: porosity, infiltration capacity, saturated hydraulic conductivity, bulk density and permeability. The positive impact was due to the pH, temperature and sodium concentration of the municipal wastewater with average values of 7.56, 28.4°C and 31.5mg/l respectively in comparison with WHO standard of 6.5 – 8.15, 20°C – 30°C and 200mg/l respectively which was within the limit and hence improved saturated hydraulic conductivity, infiltration capacity and Exchangeable Sodium Percentage (ESP) of the soil. The negative impact was due to the turbidity, conductivity and BOD of the wastewater with average values of 19.79 NTU, 619µs/cm and 16mg/l respectively in comparison with WHO standard for irrigation water of 5 NTU, 1.5µs/cm and < 6mg/l respectively which was above the limit and thus had a negative impact on soil porosity and permeability.

However, proper management of water, soil and operational procedures play an important role in the successful use of sewage effluent for irrigation. This led to the development of the guidelines proposed in this research for the effective use of wastewater for irrigation and are presented in relation to field management practices in wastewater irrigation where applicable.

The guidelines developed form a basis for further consultation involving interested researchers and they include: blending of wastewater with other water supplies, Alternating treated wastewater with other water sources, land development, Land grading, Timing of irrigation and deep cultivation

5.2 Recommended Field Management Practices in Wastewater Irrigation.

The evaluation of the results above concerning the effects of wastewater reuse for irrigation on the hydraulic properties of soil on the existing situation in Soje, Kpakungu Minna has led to the recommendations presented in this paper for developing future regulations appropriate to the conditions of the study area. The intension is to present them on the basis of rationale developed in order to form a basis for further consultation involving all interested researchers. The proposal or the recommendations are presented in relation to field management practices in wastewater irrigation where applicable.

Management of water, soil and operational procedures play an important role in the successful use of sewage effluent for irrigation. The following are recommended management practices for the effective use of wastewater for irrigation

5.2.1 Blending of Wastewater with Other Water Supplies

One of the options that may be available to farmers is the blending of wastewater with conventional sources of water, canal water or ground water that is if multiple sources are available. It is possible that a farmer may have saline waste water and, if he has non-saline treated water, could blend the two sources to obtain a blended water of acceptable salinity level. Further, by blending, the microbial quality of the resulting mixture could be superior to that of the unblended wastewater.

5.2.2 Alternating Treated Wastewater with Other Water Sources

Another strategy is to use the wastewater alternatively with the canal water or ground water, instead of blending. From the point of view of salinity control, alternate applications of the two sources will be superior to blending. However an alternating application strategy will require dual conveyance systems and availability of the effluent dictated by the alternate schedule of application

5.2.3 Land Development

During the early stages of on-farm land development, steps can be taken to minimize potential hazards that may result from the use of wastewater. These will have to be well planned, designed and executed since they are expensive and often one time operations. Their goal is to improve permanently existing land and soil conditions in order to make irrigation with wastewater easier. Typical activities include leveling of land to a given grade, establishing adequate drainage, deep ploughing and leaching to reduce soil salinity.

5.2.4 Land Grading

Land grading is well accepted as an important farm practice in irrigated agriculture. It is of great significance in achieving good uniformity of application from surface irrigation methods and acceptable irrigation efficiencies in general. Several methods are available to grade land to a desired slope. The slope required will vary with the irrigation system, length of run of water flow, soil type and the design of the field.

5.2.5 Timing of Irrigation

The timing of irrigation including irrigation frequency, pre-planting irrigation and irrigation prior to a rainy season can reduce soil deterioration and improve the hydraulic properties of soil. Pre-planting irrigation is practiced in many irrigation schemes for two reasons, namely: (i) to leach salts from the soil surface and (ii) to provide adequate moisture to germinating seeds and young seedlings. A common practice among growers of lettuce, tomatoes and other vegetable crops is to pre-irrigate the field before planting, since irrigation soon after planting could create local water stagnation and wet spots that are not desirable. Treated water is a good source for pre-irrigation.

5.2.6 Crop Selection

Not all plants respond to salinity in a similar manner, some crops can produce acceptable at much higher soil salinity than others. This is because some crops are better able to make the needed osmotic adjustment, enabling them to extract more water from a saline soil. The ability of a crop to adjust to salinity is extremely useful. In areas where a build-up of soil salinity cannot be controlled at an acceptable concentration for the crop being grown, an alternative crop can be selected that is both more tolerant of the expected soil salinity and able to produce economic yields.

5.2.7 Deep Cultivation

In certain areas, the soil is stratified, and such soils are difficult to irrigate. Layers of clay, sand or hard pan in stratified soils frequently impede or prevent free movement of water through and beyond the root zone. This will not only lead to saturation of the root zone but also to the accumulation or salts in the root zone. Irrigation efficiency as well as water movement in the soil can be greatly enhanced by sub-soiling and chiseling of the land. The effects of subsoiling and chiseling remain for about 1 to 5 years but, if long term effects are required, the land should be deep and slip ploughed. Deep or slip ploughing is costly and usually requires the growing of annual crops soon after to allow the settling of the land. Following a couple of grain crops, grading will be required to re-establish a proper grade to the land

5.3 Recommendation

i. More research should be carried out on different soil types and at various depths to see the effects of the hydraulic properties of soil

ii. Since the study was carried out only in wet season, more research should be carried out in both seasons to see whether there will be much variation in the values obtained in both seasons.

iii. More parameters should be analyzed such as soil available phosphorous and exchangeable calcium for the soil analysis and chemical oxygen demand and alkalinity for water analysis.

iv. The analysis should be carried out in different laboratories and the results compared to ensure accuracy.

v. Research should be carried out on other soil hydraulic parameters such as field capacity, refill point and soil water.

REFERENCES

Akegbejo-samsons, Y. (2008): Impact of urban agriculture on water reuse and related activities on the rural population of the coastal settlements of ondo state, nigeria. volume 8 no. 1 pp 48-62.

Alberta Environmental Protection, (1997): Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems. Edmonton, Alberta.

Amoozegar, A and Niewoehner, P (1998): Soil hydraulic properties affected by various components of domestic wastewater. pp. 155-166.

Amoozegar, A., and G. V. Wilson. (1999): Methods for measuring hydraulic conductivity and drainable porosity. pp. 1149-1205.

Anderson-Cook, C.M *et al.* (2002).Differentiating soil types using electromagnetic conductivity and crop yield maps. *Soil Science Society of America Journal* 66: pp 1562-1570.

Angelakis, A *et al.* (1995). Wastewater reclamation and reuse. Selected Proceedings of the International Association for Water Quality 2nd International symposium.

Arar, A. (in press). (2000): Introduction to the subject of the seminar. Treatment and Use of Sewage effluent for Irrigation. Buttenvorths, London.

Asano, T *et al*, (1996): Wastewater reclamation and reuse in Japan: overview and implementation examples. Water Science Technology, 34(11), pp 219–226.

Blumenthal, U. J. and Mara, D.D. (1996): Evaluation of the WHO nematode egg guidelines for restricted and unrestricted irrigation. Water Science and Technology 33(10-11): pp 277-283.

Beirut, M.R.*et al* (2001): Economic-environmental approach for optimum wastewater utilization in irrigation: a case study in Lebanon pp 41-48.

Biney, C. and Amuzu, A. T.(1994): Review of Heavy Metals in the African Aquatic Environment. Ecotoxicology and Environmental Safety 28, pp 134-159.

Chansler, J. M. (1991): The future for effluent reuse. Water/Engineering & Managemeny. 138: pp 31-34.

Chen, J. C., and Lin, C. Y. (1995): Canadian Water Quality Guideline (CWQG). Responses of Oxygen Consumption, Ammonia-N Excretion and Urea-N Excretion of Penaeus chinensis Exposed to Ambient Ammonia at Different Salinity and pH Levels. Aquaculture 136, pp 243-255. .

Desvouges et al (1986): The Conceptual Basis of Benefits Estimation in Measuring Water Quality Benefits. Ray Perryman, ed. Boston, USA: Kluwer Academic Publishers Group. pp 327.

Dane, J. and Hopmans, J. (2002): Water retention and storage: Laboratory. In J. H. Dane, and J. W. Hopmans (ed.) Methods of Soil Analysis, Part 4, Physical Methods. Soil Sci. Soc. of America, Madison, WI. pp 675-690.

Ernestova, L. S. and Semenova, I. V. (1994): The Self-purification resources farming in Conejos County, Colorado. Water Resources. Res. 29(2): pp 229-235.

Elrick, D.E. (1991): Determination of Hydraulic Conductivity Using a Tension Infiltrometer, Soil Science Society of Americal Journal 55: pp 633-639.

Fisher, D. J., Knott, M. H., Turley, B. S., Yonkos, L. T., Ziegler, G. P. (1998). Acute and Chronic Toxicity of Industrial and Municipal Effluents in Maryland, U.S. Water Environment Research 70 (1). pp 101-107.

Feenstra, S. Hussein, R. Van der Hoek, W. (2000): Health risk of Irrigation with untreated urban wastewater. Report 107.

Flessa, H. and Beese, F. (1995): Effects of sugarbeet residues on soil redox potential and nitrous oxide emission. Soil Sci. Soc. Am. J. 59: pp 1044–1051.

Freeman, J. (1993): Values in an Uncertain World in The Measurement of Environmental and Resource Values: Theory and Methods. Washington, USA: Resources for the Future. pp 516.

Fakayode, S. O. (2000): Lead Contamination of Topsoil and Vegetation in the Vicinity of a Battery Factory in Nigeria. Environmental Geochemistry and Health 22, pp 211-218.

Ferreira, A.M., Rangel, A.O. and Lima, F.C. (1998): Flow injection system for elemental soil analysis determination. Comm. Soil Sci. Plant Anal., 29(344): pp 327–360.

Fakayode S. O (2005): Impact assessment of industrial effluent on water quality of the receiving alaro river in ibadan, nigeria. ajeam-ragee volume 10 pp1-13.

Gasparon, M. and Burgess, J. S. (2000): Human Impacts in Antarctica: Trace Element Geochemistry of Freshwater Lakes in the Larsemann Hill, East Antarctica. Environmental Geology 39 (9), pp 963-976.

Gbegbelegbe, S.D. (2002): Defining and Achieving the Water Quality Standard in Total Maximum Daily Load (TMDL) Environmental Regulations: Conference ASAE Pub. 701P0102 pp. 325-332

Haruvy, N. (1997): Agricultural reuse of wastewater:Nation-wide cost-benefit analysis. Agric., Ecosystems and Environment 66: pp 113-119.

Hespanhol, I. (1993): Reuse of community wastewater: health and environmental protection – research needs. In: FAO, Integrated rural water management: Proceedings of the Technical Consultation on Integrated Rural Water Management, Rome, Italy,. Rome, Italy: FAO. pp 121-138.

Helfand, O. (1991): Standards versus Standards: The Effects of Different Policy Restrictions. The American Economic Review 81 (3): pp 622-634.

Haines, T. A. (1981): Acidic Precipitation and its Consequences for Aquatic Ecosystems: A Review. Transactions American Fisheries Society. 110 (6). pp 669-707.

Kudryavtseva, L. P. (1999): Assessment of Drinking Water Quality in the City of Apatit. Water

Resources 26(6). pp 659-665.

Mori, A. (1993): Treatment and Recycling of Sewage Sludge in Yokohama, Proceedings of the 15th Federal Convention of Australian Water and Wastewater Association, 11993, pp 682-688.

McKitrick, H. (1999): Policy Options and Examples in Environmental Economics: Course Readings. Insta-Print; Guelph; pp.33-56.

Minasny, B. McBratney, A.B. (2001): The Australian soil texture Boomerang: A Comparison of the Australian and USDA/FAO Soil Particle Size Classification Systems, Australian Journal of Soil Research, 39: pp 1443-1451.

Moiseenko, T. I. (1999): Assessment of Environmental Hazard due to Water Pollution by Metals. Water Resources 26(2). pp 162-173.

Neal, C. and Robson, A. J. (2000): A Summary of River Water Quality Data Collected Within the Land-Ocean Interaction Study: Core Data for Eastern UK Rivers Draining to the North Sea. Science of the Total Environment 251/252. pp 585-665

Offiong, O. E. and Edet, A. E. (1998): Water Quality Assessment in Akpabuyo, Cross River Basin, South-eastern Nigeria. Environmental Geology 34(2&3), pp 167-174.

Olajire, A. A. and Imeokparia, F. E. (2001): Water Quality Assessment of Osun River: Studies on Inorganic Nutrients. Environmental Monitoring and Assessment 69. pp 17-28.

Pescod, M.B. (1992): Wastewater treatment and use in agriculture, FAO Irrigation and drainage paper 47. pp 18-24.

Rhoades, J. D. and Loveday, J. (1990): Salinity in irrigated agriculture. In B. A. Stewart, and D. R. Nielsen (ed.). Irrigation of Agricultural Crops. 2nd Ed., Agron. Monogr. 30. Am. Soc. Agron., and Soil Sci. Soc. Am., Madison, WI. pp 1089-1142.

Robson, A. J. and Neal, C. (1997): A Summary of Regional Water Quality for Eastern UK Rivers. Science of the Total Environment 194 &195, pp 15-39.

Scott C.A and Faruqui, N.I. (2002): Wastewater use in irrigated Agriculture. Pg 1-24.

Spangler, M.G. (1993): Soil Engineering. Third edition. Intex educational Publishers. Pg 161-236.

Seleznev, V. A. and Selezneva, A. V. (1999): Evaluation of the Impact of Wastewater from Tolyatti on Water Quality in the Saratov Reservoir. Water Resources 26(3), pp 316-320.

Stamatis, G. (1999): The Chemical Composition of the Surface System of Peneos River, Thessaly/Central Greece. Environmental Geology 38(2), pp 126-140.

Sobieraj, J.A., Elsenbeer, H. and Vertessy, R.A. (2001): Pedotransfer functions for estimating saturated hydraulic conductivity: implications for modelling storm flow generation, Journal of Hydrology, 251: pp 202-220.

Tsuranich, T.M. and Krut, V.V. (1993): Chemical Composition of the Danube River. Water Resources 20 (4), pp 440-446.

Wösten, J.H., Pachepsky, Y.A. and Rawls, W.J. (2001): "Pedotransfer functions: bridging the gap between available basic soil data and missing soil hydraulic characteristics". Journal of Hydrology 251: pp 123–150.

WHO (World Health Organization) (1989): Health guidelines for the use of wastewater in agriculture and aquaculture. WHO Technical Report Series 778 Geneva, Switzerland: World Health Organization. pp 58-70.

Zureik, R. and Rizk C (1992): Treatment of sewage water using aquatic plants and its applicability in Lebanon. In Proc. Conference on Water Supply in Lebanon, pp 27-28

APPENDICES

Appendix I

Wastewater Treatment

The principal objective of wastewater treatment is generally to allow human and industrial effluents to be disposed of without danger to human health or unacceptable damage to the natural environment. Irrigation with wastewater is both disposal and utilization and indeed is an effective form of wastewater disposal (as in slow-rate land treatment). However, some degree of treatment must normally be provided to raw municipal wastewater before it can be used for agricultural or landscape irrigation or for aquaculture. The quality of treated effluent used in agriculture has a great influence on the operation and performance of the wastewater-soil-plant or aquaculture system. In the case of irrigation, the required quality of effluent will depend on the crop or crops to be irrigated, the soil conditions and the system of effluent distribution adopted. Through crop restriction and selection of irrigation systems which minimize health risk, the degree of preapplication wastewater treatment can be reduced. A similar approach is not feasible in aquaculture systems and more reliance will have to be placed on control through wastewater treatment. The most appropriate wastewater treatment to be applied before effluent use in agriculture is that which will produce an effluent meeting the recommended microbiological and chemical quality guidelines both at low cost and with minimal operational and maintenance requirements (Arar 1998). In many locations it will be better to design the reuse system to accept a low-grade of effluent rather than to rely on advanced treatment processes producing a reclaimed effluent which continuously meets a stringent quality standard. Nevertheless, there are locations where a higher-grade effluent will be necessary and it is essential that information on the performance of a wide range of wastewater treatment technology should be available. The design of wastewater treatment plants is usually based on the need to reduce organic and suspended solids loads to limit pollution of the environment. Pathogen removal has very rarely been considered an objective but, for reuse of effluents in agriculture, this must now be of primary concern and processes should be selected and designed accordingly (Hillman 1998). Treatment to remove wastewater constituents that

may be toxic or harmful to crops, aquatic plants (macrophytes) and fish is technically possible but is not normally economically feasible. Unfortunately, performance data on wastewater treatment plants in developing countries are available and even then they do not normally include effluent quality parameters of importance in agricultural use. The short-term variations in wastewater flows observed at municipal wastewater treatment plants follow a diurnal pattern. Flow is typically low during the early morning hours, when water consumption is lowest and when the base flow consists of infiltration-inflow and small quantities of sanitary wastewater. A first peak of flow generally occurs in the late morning, when wastewater from the peak morning water use reaches the treatment plant, and a second peak flow usually occurs in the evening. The relative magnitude of the peaks and the times at which they occur vary from country to country and with the size of the community and the length of the sewers. Small communities with small sewer systems have a much higher ratio of peak flow to average flow than do large communities. Although the magnitude of peaks is attenuated as wastewater passes through a treatment plant, the daily variations in flow from a municipal treatment plant make it impracticable, in most cases, to irrigate with effluent directly from the treatment plant. Some form of flow equalization or short-term storage of treated effluent is necessary to provide a relatively constant supply of reclaimed water for efficient irrigation, although additional benefits result from storage.

APPENDIX II

Crop Selection to Overcome Salinity Hazards

Not all plants respond to salinity in a similar manner; some crops can produce acceptable yields at much higher soil salinity than others. This is because some crops are better able to make the needed osmotic adjustments, enabling them to extract more water from a saline soil. The ability of a crop to adjust to salinity is extremely useful. In areas where a build-up of soil salinity cannot be controlled at an acceptable concentration for the crop being grown, an alternative crop can be selected that is both more tolerant of the expected soil salinity and able to produce economic yields. There is an 8-10 fold range in the salt tolerance of agricultural crops. This wide range in tolerance allows for greater use of moderately saline water, much of which was previously thought to be unusable. It also greatly expands the acceptable range of water salinity (ECw) considered suitable for irrigation. The relative salt tolerance of most agricultural crops is known well enough to give general salt tolerance guidelines. Below presents a list of crops classified according to their tolerance and sensitivity to salinity.

Relative Salt Tolerance of Agricultural Crops

TOLERANT

Fibre,	Seed and Sugar Crops
Barley	*Hordeum vulgare*
Cotton	*Gossypium hirsutum*
Jojoba	*Simmondsia chinensis*
Sugarbeet	*Beta vulgaris*
<u>Grasses and Forage Crops</u>	
Alkali grass	*Puccinellia airoides*

Alkali sacaton	*Sporobolus airoides*
Bermuda grass	*Cynodon dactylon*
Kallar grass	*Diplachne fusca*
Saltgrass, desert	*Distichlis stricta*
Wheatgrass, fairway crested	*Agropyron cristatum*
Wheatgrass, tall	*Agropyron elongatum*
Wildrye, Altai	*Elymus angustus*
Wildrye, Russian	*Elymus junceus*
<u>Vegetable Crops</u>	
Asparagus	*Asparagus officinalis*
<u>Fruit and Nut Crops</u>	
Date palm	*Phoenix dactylifera*
MODÉRATELY TOLERANT	
<u>Fibre, Seed and Sugar Crops</u>	
Cowpea	*Vigna unguiculata*
Oats	*Avena sativa*
Rye	*Secale cereale*
Safflower	*Carthamus tinctorius*
Sorghum	*Sorghum bicolor*
Soybean	*Glycine max*
Triticale	*X Triticosecale*
Wheat	*Triticum aestivum*
Wheat, Durum	*Triticum turgidum*

Grasses and Forage Crops

Barley (forage)	*Hordeum vulgare*
Brome, mountain	*Bromus marginatus*
Canary grass, reed	*Phalaris, arundinacea*
Clover, Hubam	*Melilotus alba*
Clover, sweet	*Melilotus*
Fescue, meadow	*Festuca pratensis*
Fescue, tall	*Festuca elatior*
Harding grass	*Phalaris tuberosa*
Panic grass, blue	*Panicum antidotale*
Rape	*Brassica napus*
Rescue grass	*Bromus unioloides*
Rhodes grass	*Chloris gayana*

Grasses and Forage Crops

Ryegrass, Italian	*Lolium italicum multiflorum*
Ryegrass, perennial	*Lolium perenne*
Sudan grass	*Sorghum sudanense*
Trefoil, narrowleaf birdsfoot	*Lotus corniculatus tenuifolium*
Trefoil, broadleaf	*L. corniculatus arvenis*
Wheat (forage)	*Triticum aestivum*
Wheatgrass, standard crested	*Agropyron sibiricum*
Wheatgrass, intermediate	*Agropyron intermedium*
Wheatgrass, slender	*Agropyron trachycaulum*

Wheatgrass, western	*Agropyron smithii*
Wildrye, beardless	*Elymus triticoides*
Wildrye, Canadian	*Elymus canadensis*
<u>Vegetable Crops</u>	
Artichoke	*Helianthus tuberosus*
Beet, red *Beta*	*vulgaris*
Squash, zucchini	*Cucurbita pepo melopepo*
<u>Fruit and Nut Crops</u>	
Fig	*Ficus carica*
Jujube	*Ziziphys jujuba*
Olive	*Olea europaea*
Papaya	*Carica papaya*
Pineapple	*Ananas comosus*
Pomegranate	*Punica granatum*
MODERATELY SENSITIVE	
<u>Fibre, Seed and Sugar Crops</u>	
Broadbean	*Vicia faba*
Castorbean	*Ricinus communis*
Maize	*Zea mays*
Flax	*Linum usitatissimum*
Millet, foxtail	*Setaria italica*
Groundnut/peanut	*Arachis hypogaea*
Rice, paddy	*Oryza sativa*

Sugarcane	*Saccarum officinarum*
Sunflower	*Helianthus annuus palustris*
<u>Grasses and Forage Crops</u>	
Alfalfa	*Medicago sativa*
Bentgrass	*Agrostisstoloniferapalustris*
Bluestem, Angleton	*Dichanthium aristatum*
Brome, smooth	*Bromus inermis*
Buffelgrass	*Cenchrus ciliaris*
Burnet	*Poterium sanguisorba*
Clover, alsike	*Trifolium hydridum*
<u>Grasses and Forage Crops</u>	
Clover, Berseem	*Trifolium alexandrinum*
Clover, ladino	*Trifolium repens*
Clover, red	*Trifolium pratense*
Clover, strawberry	*Trifolium fragiferum*
Clover, white Dutch	*Trifolium repens*
Corn (forage) (maize)	*Zea mays*
Cowpea (forage)	*Vigna unguiculata*
Dallis grass	*Paspalum dilatatum*
Foxtail, meadow	*Alopecurus pratensis*
Grama,	vlue *Bouteloua gracilis*
Lovegrass	*Eragrostis sp.*
Milkvetch, Cicer	*Astragalus deer*

Oatgrass, tall	*Arrhenatherum, Danthonia*
Oats (forage)	*Avena saliva*
Orchard grass	*Dactylis glomerata*
Rye (forage)	*Secale cereale*
Sesbania	*Sesbania exaltata*
Siratro	*Macroptilium atropurpureum*
Sphaerophysa	*Spaerophysa salsula*
Timothy	*Phleum pratense*
Vetch, common	*Vicia angustifolia*
Vegetable Crops	
Broccoli	*Brassica oleracea botrytis*
Brussel sprouts	*B. oleracea gemmifera*
Cabbage	*B. oleracea capitata*
Cauliflower	*B. oleracea botrytis*
Celery	*Apium graveolens*
Corn, sweet	*Zea mays*
Cucumber	*Cucumis sativus*
Eggplant	*Solanum melongena esculentum*
Kale	*Brassica oleracea acephala*
Kohlrabi	*B. oleracea gongylode*
Lettuce	*Latuca sativa*
Muskmelon	*Cucumis melon*
Pepper	*Capsicum annum*

Potato	*Solanum tuberosum*
Pumpkin	*Cucurbita peop pepo*
Radish	*Raphanus sativus*
Spinach	*Spinacia oleracea*
Squash, scallop *C.*	*pepo melopepo*
Sweet potato	*Ipomoea batatas*
Tomato	*Lycopersicon lycopersicum*
Turnip	*Brassica rapa*
Watermelon	*Citrullus lanatus*
Fruit and Nut Crops	
Grape	*Vitis sp.*
SENSITIVE	
Fibre, Seed and Sugar Crops	
Bean	*Phaseolus vulgaris*
Guayule	*Parthenium argentatum*
Sesame	*Sesamum indicum*
Vegetable Crops	
Bean	*Phaseolus vulgaris*
Carrot	*Daucus carota*
Okra	*Abelmoschus esculentus*
Onion	*Allium cepa*
Parsnip	*Pastinaca sativa*
Fruit and Nut Crops	

Almond	*Prunus dulcis*
Apple	*Malus sylvestris*
Apricot	*Prunus armeniaca*
Avocado	*Persea americana*
Blackberry	*Rubus sp.*
Boysenberry	*Rubus ursinus*
Cherimoya	*Annona cherimola*
Cherry, sweet	*Prunus avium*
Currant	*Ribes sp.*
Gooseberry	*Ribes sp.*
Grapefruit	*Citrus paradisi*
Lemon	*Citrus limon*
Lime	*Citrus aurantifolia*
Loquat	*Eriobotrya japonica*
Mango	*Mangifera indica*
Orange	*Citrus sinensis*
Passion fruit	*Passiflora edulis*
Peach	*Prunus persica*
Pear	*Pyrus communis*
Persimmon	*Diospyros virginiana*
Plum: Prune	*Prunus domestica*
Pummelo	*Citrus maxima*
Raspberry	*Rubus idaeus*

Syzgium jambos

Casimiroa edulis

Fragaria sp.

Citrus reticulate