IMPACT OF SALTS BUILD-UP ON SOIL AND WATER QUALITY

A CASE STUDY OF HAYIN GWARI OKADA IRRIGATION SCHEME

BY

MUHAMMED MUSA ISAH
PGD/AGRIC/98/99/49

DEPARTMENT OF AGRICULTURAL ENGINEERING, SCHOOL OF ENGINEERING AND ENGINEERING TECHNOLOGY,
POST GRADUATE SCHOOL
FEDERAL UNIVERSITY OF TECHNOLOGY,
MINNA.

AUGUST, 2000

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A CASE STUDY OF HAYIN GWARI OKADA IRRIGATION SCHEME IN BOSSO LOCAL GOVERNMENT AREA OF NIGER STATE

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SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE
AWARD OF THE DEGREE OF POST GRADUATE DIPLOMA (PGD) IN
AGRICULTURAL ENGINEERING OF FEDERAL UNIVERSITY OF
TECHNOLOGY, MINNA

AUGUST, 2000

DECLARATION

I hereby declare that this project has been conducted by me under the guidance of my supervisor Engineer N. A. Egharevba and the co-supervisor in person of Engineer Muhammed Bashir of Agricultural Engineering Department of School of Engineering and Engineering Technology, Federal University of Technology, Minna.

It is neither a duplicate of any other thesis nor someone else did it for me.

Authors whose works have been referred to are duly acknowledged.

MUHAMMED MUSA ISAH
STUDENT'S NAME

SIGNATURE

31ST AUGUST 2000.
DATE

APPROVAL PAGE

This project has been read and approved as meeting post graduate Diploma (Agricultural/Engineering) requirement of the Department of Agricultural Engineering, School of Engineering and Engineering Technology, Post Graduate School, Federal University of Technology Minna, Niger State.

23/07/2001

Engr. N. A. Egharevba — Date
Project Supervisor

Engr. Muhammed Bashir — Date
Co-Supervisor

Dr. M. G. Yisa — Date
Head of Department

Date
External Examiner.

DEDICATION

This project is dedicated to Almighty Allah for His guidance, my Parents Mr. And Mrs Musa Akaya and to the entire course of alleviating poverty from our society by humanity.

ACKNOWLEDGEMENT

I, acknowledge the utmost help of Almighty Allah for guiding me through the period of the course and making me finish the project and programme successfully.

My sincere gratitude goes to my supervisor Engineer N. A. Egharevba and my Co-supervisor Mallam Muhammed Bashir who, have most efficiently and professionally guided me through the project. Words alone cannot quantify their contributions and assistance. May Allah Bless them abundantly, Amen. Also my sincere greetings go to Mallam Muhammed Abdulmalik and Mr. Idoko of the Soil Science Laboratory in the School of Agricultural Technology, they saw me through the analysis of the soil and water that were used.

Moreso, I do sincerely acknowledged the departmental lecturers who made the programme to be successful and worth the salt in persons of Dr. M. G. Yisa, Dr. D. Adgidzi, N. A. Egharevba, Dr. Jimoh, Mrs. Osunde, Mr. B. Alabadan, Dr. Ajisegiri, Mr. O. s. Ayodeji, Engr. Chukwu.

My thanks and gratitude goes to Alhaji Yunusa Yusuf and his family for their unflinching supports in so many ways beyond words can describe.

Also, my greetings go to my colleagues in the Federal Department of Agriculture, Engineering Division in persons of Engineers M. C. C. Eneh, J. A. Dairo, M. O. Akeju, M. O. Owolabi, A. G. Abubakar, A.O.G.O. Abdulsalam, A. E. Ishola; Mr. Edet Antai who help in the typing of the project.

I shall also acknowledge my friends in persons of Tijani Haruna, Joyce Samuel, Peter Enegola, Daniel Sakpame, Ahmed Shekarou, Abigeal Joseph, Hanatu Launar, Mallam Muhammed Aliyu and my lovely sister and her daughter by names Ramatu Musa and Ojochide Omattah.

Worthy of praise are my course mates who are Mallam Muhammed Sani Bala, Mr. Dunama Makama Iliya, Isa Musa, Bisssalah, Sowunmi Isiwat Olajumoke, Abdullahi Kola, Nasiru Abdullahi Illo, Musa Ahmed; Ogunmola Olawoyin and those that their names were not mentioned.

The entire staff and management of Maradiq Guest Inn in Tunga Low-Cost Housing, Minna.

I acknowledge the help of friends, brothers, sisters, relatives and well-wishers whose names are so numerous to be named in this place, that may the Blessings of Almighty Allah be upon them all; Amen.

ABSTRACT

An assessment of the impact of salts build-up on soil and water quality in Hayin Gwari Okada Irrigation scheme was carried out. Physico-Chemical properties of the soil and water representative samples were analyzed, at the upstream and downstream of the irrigable area. The electrical conductivity has increased from 68 micromhos/cm upstream to 83.5micromhos/cm downstream, the Sulphate anions also increased from 2.51mg/l upstream to 24.1mg/l downstream of the water samples considered. The exchangeable sodium cations at the depth of 0.60cm has an average rating of 0.63 downstream and 0.31 upstream indicating high increase of exchangeable cations. The impact of salts build-up in the irrigation scheme is as a results of the low quality, of water used for irrigation, the accumulation of salts in the soil due to evapotranspiration application of fertilizer and lack of adequate drainage of the irrigated area.

LISTS OF TABLES

TABLE OF CONTENTS

CHAPTER ONE

CHAPTER TWO

CHAPTER THREE

CHAPTER FOUR:

CHAPTER FIVE

5.5 Appendix

CHAPTER ONE

1.0 INTRODUCTION

Extensive areas of land in the arid and semi-arid regions of the world have gone out of cultivation due to the rise of water table and accumulations of salt. Excessive irrigation and poor water management are the chief causes of water logging and salt-build-up in irrigated agriculture.

Development of soil salinity is a challenge to the permanence of irrigated agriculture. An accumulation of salts in soils lead to unfavourable soil-water-air relationships and decreases crop production. Gradually, the land goes out of cultivation, unless remedial measures are undertaken.

Salinity is a major problem in irrigated agriculture. Through evapotranspiration, salts in the irrigation water become more concentrated in the drainage effluent. It is therefore claimed, that water quality is seriously impaired by irrigated agriculture.

Irrigation water always contains some salt, most of which is excluded by the plant roots; since the evaporated water is pure, the soil accumulates the residual salt, which is added to what the arid soils already have in abundance. This accumulation of salt must be removed if plants are to be grown at all, and it is removed by leaching with excess water and application of fertilizer.

Survival of an irrigated area will depend, therefore, on a favourable salt balance; salt leaving the area must equal or exceed that received in the water supply.

The irrigation farmer is not actually "producing" a contaminant but is transferring one in a more concentrated form. Future intensified use of limited irrigation water may add to the severity of this problem. Where the return flow is readily recoverable, as from Tile drains or pumped wells, it could be purified by a desalination process, returning the purified fraction to the water courses and disposing of the concentrated salt fraction in such a way that usable groundwater is not affected (Encyclopaedia Britannica 1994-1999).

Okada small scale scale irrigation scheme is in Hayin Gwari' district of Bosso Local Government Area of Niger State has a land area of about 9.75 hectares put into use under dry season irrigated agriculture.

The scheme is being serviced by River Bosso in Bosso Local Government Area of Niger State. The area has been in use for some decades now, which has led to the salt build-up problems of the scheme.

1.1 AIMS AND OBJECTIVES

(a) Analysing quality of water used for irrigation

(b) Analysing the quality of soil used for irrigation

(c) Assess the impact of salts on the soil properties in the irrigation scheme and also assessing the impact of soils on surface water before and after it has entered the scheme.

1.2 STATEMENT OF THE PROBLEM:

This is to allow for the determination of the various salts and their compositions in the soil and water used in the scheme.

The problem of improved seedlings and varieties of some crops grown in the scheme and the use of some fertilizers that not in conformity with the Crops.

Excessive irrigation and poor water management, which cause accumulations of salts leading to unfavourable soil-water-air relationship, which decrease crop production.

1.3 JUSTIFICATION:

Salts build-up due to continuous irrigation with low quality water, there is a need to evaluate the impact of these salts on the soil and water to allow for proper solutions on the salts build-up in the Okada Irrigation scheme. This problem has adversely affected the rate of production and cultivation of the fields.

The quality of water, if it is suitable for irrigation and if the electrical conductivity of the water has been exceeded and the tolerant level of the various crops in the scheme, will definitely have negative impact on the soil productivity level.

1.4 SCOPE OF STUDY:

This covers the area of the scheme that is being used for dry season (irrigation) farming.

Some low quality waters are characterized with high salts content and therefore with increased probabilities of creating soil, water and crop problems. High sodium content in irrigation water may reduce plant growth due to reduced soil permeability and aeration. The nutrients in treated waste water provide fertilizer value, but where plant needs are exceeded, may cause growth, problems and reduction of crop yields. This will also render the soil barren and will send some farmers out of production.

The scope of the study is to overcome all these problems and to help the farmers with some professional advices and good farming systems.

1.5 HISTORICAL BACKGROUND OF BOSSO LOCAL GOVERNMENT AREA, MAIKUNKELE:

The Bosso Local Government Area of Niger State was carved out of the former Chanchaga Local Government on Friday 27th September, 1991 along with Paikoro, Gurara, Gbako and Agwara Local Government Areas by the former Military President General Ibrahim Badamosi Babangida.

Maikunkele which is the Headquarters of Bosso Local Government has about 1½ square kilometers to the North-West of Minna international Airport and about 12 km drive from the Centre of Minna metropolis along Zungeru Road, with about 338.4 hectares of land.

The Local Government Area has a population of about 106,874 people based on the 1991 population census final figures.

Bosso Local Government Area is positioned along longitude 06° 20′ E and Latitude 9° 30′N of the equator and is located at Eastern quarter on the West – East axis.

The Local Government Area has a land mass which completely enveloped Minna Local Government Area, that is Minna metropolis and bounded to the North and North-East by Shiroro Local Government, to the South-East by Paikoro Local Government, to the South by Bida Local government Area, this then makes it nearly equal distance from the extreme corner of the State. It is also bounded by Wushishi Local Government Area on the South-Western axis.

1.5.1 CLIMATE:

The climate of the area has a semblance of Tropical Regions of the world. The major wind directions are normally along South-West and North-East axis.

The rainy season last between 190 – 200 days (6 – 7 months), while about 1,350mm (54 inches) with September recording the highest rains of 300mm (11.7 inches). Mean monthly temperature is higest in March at 35°C (88°F) and the lowest at 25°C (75°F).

1.6 ECONOMIC ACTIVITIES:

The major occupation of the people within the area is farming, mainly rainfed agriculture and partly irrigated agriculture is being practice along the river banks in the area. Fishing and rearing of animals are also carried out by the people.

The land is arable for the cultivation of most staple food crops and some cash crops too, vegetables and fruits on an enormous scales e.g. yam, rice, guinea corn, groundnut, maize, cassava, cocoa, kolanut.

The dry season period between the months of November to May is the period when the irrigation practice is carried out, to argument for the rainfed agriculture in the cultivations of such crops like; vegetables, fruits, root tubers, cereals and cash crops.

1.7 RECONNAISANCE SURVEY:

The reconnaissance survey was undertaken by the use of a tape rule on both sides of the river. This is because the river has divided the Okada Irrigation Scheme into two parts, that is one part at the northern axis and the other part is at the

Southern axis. The Northern part of the scheme was measured.

1.8 THE AREA OF THE SCHEME:

The area of the scheme was measured and labelled as sites A and B. respectively.

Site A (Farm land) = 150 x 450m = 67,500m^2

Site B (Farm land) = 150 x 200m = 30,000m^2

Total area (Farm land) = 97,500m^2

The total farm land was converted to hectares.

Therefore 97,500m^2 converted to hectares.

10,000m^2 equal to 1 hectare

$$= \frac{97,500}{10,000} = 9.75 \text{ hectares}$$

Therefore the Okada Irrigated Scheme is about Ten (10) hectares of farm land.

1.9.0 THE FARM HOLDING UNITS:

The farm holding units in the Okada Irrigation Scheme is divided into seven (7) portions or units. These seven units are further sub-divided into smaller units to enable the farmers to practice the various types of farming and cropping systems in the scheme.

The farm holding systems have been adopted and practiced by the farmers and this has been passed on from family to family for some decades now. The larger holding units are being controlled by the heads of the family.

1.9.1 THE SAMPLING POINTS

SAMPLING POINTS FOR WATER

The sampling points of water were carried out at 100m apart. At the upstream section of the river Bosso, the first point of sample was at the very junction where Julius Berger Nigeria Plc stopped their profiling of the erosion control of the river. The second sampling point at the upstream was 100m inside the scheme before the water was damed and pumped into the scheme for use by the farmers.

After the use of the water in the various units in the scheme, the water is then pumped back into the river at the downstream section. At the downstream section of the river, two sampling points were identified and taken, at about 100m apart from the irrigation scheme. See appendix 5.

These points were chosen to enable me ascertain the amount of salts being carried by the water before it enters into the scheme for use. When the water has been used to irrigate the farmland, it carried and absorbed more salts from the scheme.

The source of water samples were labeled as collected in the area as follows:

UPS1, UPS2, DNS1, DNS2 respectively.

Where:

UPS1 & UPS2 = Upstream sections 1 and 2

DNS1, DNS2 = Downstream sections 1 and 2.

The water that is being used to service the Okada small irrigation scheme comes from the river Bosso, which is channel through Bosso town. The water has a lot of salt, in it and thereby hampering some crops to grow well. The yields of these crops have adversely been reduced. The soil has been rendered sterile, the salt built-up in the soil is causing untold problems to the farmers. The water quality that is being used has a lot of salts that are very dangerous to the plants, soil and human beings.

These chemicals that are present in the water at the upstream section of the river are assumed to have low salt and those that are in the irrigated areas, compared to the salts that are present in the water after it has been used for irrigating the farmland.

The impacts of these salts on plants, soil and water quality is what this project tends to address, in such a way as to profer solutions and to taking the chemical analysis of these salts. Salinity is a great problem facing these farmers.

1.9.2 **SAMPLING POINTS OF SOIL:**

The sampling points of soil were carried out at a distance of 100m apart within the irrigated area of the scheme. It was diagonally taken along the 100m distances. There are four sampling points within the farm and two points outside of the scheme that is one point at the upstream and one point downstream respectively to ascertained the salt contents of the soil. See appendix 6.

1.9.3 **AUGER POINTS/DEPTH**:

The Auger depths were variously taken to though the soil profile at depths of 0 – 20, 20 – 40, 40 – 60cm respectively, to give a true representation of the soil profile. At each varying depth, the salts content was considered for each depth. These depths were considered because, they will enable me to know the extent of salts in the soil profile and to know the type of fertilizer to recommend to the farmers.

1.9.4 **THE TEXTURAL CLASSIFICATION:**

The textural classification of the soil determined through the identification of the percentages of the sand, silt and clay respectively (appendix 2).

The use of the Textural Triangle for class identification and the particle size Analysis (PSA). The soil samples were bulked at each Auger point, sampled and analysed respectively. The soil in the scheme was discovered to be sandy loam after the group were analyzed.

For the bulk density (bd), clod method was used.

1.9.5 **THE TYPES OF PUMP USED IN THE SCHEME**:

There are basically two types of irrigation pumps that are being used for the irrigation of the scheme.

The pumps are of Yamaha and Honda brand and they are of 7.5 Hp types. They were purchased through the various contributions of the farmers that are using the scheme.

There are also two types of hoses in the scheme being used by the two pumping machines. The lengths of the hoses are about 2 and 3m respectively. There are other hoses of shorter lengths in the farm.

1.9.6 TYPES OF CROPS THAT ARE GROWN IN THE IRRIGATION SCHEME:

There are various types of crops that are grown in Okada Irrigation scheme. The crops in the farm can be grouped into:

a) Annual Crops: These are crops which grow and mature within one year e.g. maize (Zea mays), Rice (Oryza Sativa), Millet, Vegetables, groundnut (Arachis hypogea) Guinea corn, beans, carrot, tomatoes (Lycopersicon esculentum).

b) Biennial Crops: These are crops which grow and mature within two years e.g. pepper (capsicum spp), ginger, cassava (Manihot spp) etc.

c) Perennial Crops: These are crops which grow and mature more than two years e.g. Banana (Musa spp), orange (citrus sinensis), mango (mangifera Indica) etc.

These crops can be classified based on their uses as follows:

i) Cereal Crops: These crops belong to the grass family and they provide carbohydrate e.g. maize (zea mays) rice (oryza sativa), millet, guinea corn sugar cane, (sacchrum officinorum), sorghum (sorghum vulgare);

ii) Pulses (or grain legumes): These crops are rich sources of proteins e.g. bean (cowpea – vigna unguiculata), soyabeans, groundnut (Arachis hypogea), lima bean, pigeon pea etc.

iii) Vegetable Crops: These crops provides vitamins and minerals e.g. Tomato (Lycopersicon esculentum), Okra (Habiscus esculentus), amaranthus, onion (Alium sepa), cauliflower, spinach, bitter leaf, cocochoros spp, cabbage, Lıttuce, cucumber, pumpkins.

iv) Roots and tuber crops: These crops produce tubers under the ground and they provide carbohydrates e.g. cassava (manihot spp), yam Dioscorea spp), cocoyam, sweet potatoes (Ipomea butata), irish potato, carrot, etc.

v) Fruits Crops: These also provide vitamins and minerals e.g. orange (citrus sinensis), banana (musa spp), pineapple, mango (mangifera indica), pap-paw (Carica papaya), cashew (Anacadium occidental), guava (psidium guajava).

vi) Spices: these also provide vitamins and minerals. It also adds flavour to our stew or soup e.g. ginger, pepper (Capsicum spp), onion (Alium sepa) etc.

vii) Oil Crops: These are crops which can provide oil when processed both for domestic and industrial uses e.g. groundnut (Arachis hypogea), melon (Penesetium spp) soyabean, cotton (Gossipium Hirsutum).

CHAPTER TWO

2.0 LITERATURE REVIEW

Irrigation has been used as tool by humans for over 8,000 years. Irrigation started in the Nile Valley where humans attempted to modify the way that the river seasonally flooded their fields in order to make croplands more productive (Van Schilfgaarde, 1994). From 1940 to 1989 the amount of land being irrigated around the world has increased at a rate of 2.7% per year. In 1940 there were 95 million hectares in irrigation while by 1989 there were 280 million hectares (Van Schilfgaarde, 1994). This large increase in land under irrigation occurred at the same time as an exponential jump in human population, and increases in both are greatest in the arid regions of the Earth. Our population has therefore become reliant on irrigation to fend off large scale hunger (Abrol et al.., 1988).

If these salts become too concentrated it can lead to salinization. Salinization can reduce yields in it's earliest stages and eventually lead to the destruction of fertility in the soil. Currently the earth is losing 3 hectares of arable land a minute to the effects of salinization (Abrol et al.., 1988). Can we stop this less? Will we be able to continue using arid lands to meet our food needs? If yes, then urgent and drastic measures have to be taken to reduce the impacts of salts on our lands and water that are used for irrigation.

Salinization has direct impacts on both plant growth and the structure of the soil. If the soil is saline a plant will have to expend energy bringing water into it's cells because it is forced to work against osmotic potentials. The cation exchange complex (CEC) effects the stability of colloid size particles in the soil. The cation's positive charge will be attracted to the negative charge found on clay particles which makes up most of the colloid fraction. Di-Viliant cations (Ca, Mg) will allow the colloidal particle to get close enough together that Van Dehr Wahls forces will cause the clays to flocculate, or form stable aggregates.

Sodic soils, whose CEC is dominated by mono-valiant sodium cations, will tend to be dispersed and not form stable aggregates. Sodium is now mono-valiant and can not pull the colloid particles close enough together for the short range Van- Dehr Wahls forces to act (Munns et al., 1996). Sodic soils will tend to have a dark, organic appearance; due to the dispersion of clay and organic particles while saline soils will tend to have a white crusty surface due to the precipitation of salts (Lax et al., 1994). Both of these effects will lead to decreased permeability and hydraulic conductivity.

The quality of water used for irrigation has an effect on soil salinization. Surface water can vary greatly in the amount of salts that it carries in solution. Most large rivers in the world carry about 11 to 18g of dissolved materials per litre of water.

Small water courses tend to have more dissolved material and rivers tend to increase in dissolved load as they travel from their sources (Szabolcs, 1986). In some regions of the world irrigation water is predominantly pumped from aquifers and the dissolved load of ground water will vary greatly due to local lithology.

2.1 ORIGIN AND CAUSES OF SALT BUILD-UP IN IRRIGATED SOILS:

Salt affected soils occur in Africa, as in other parts of the world, mostly in the arid and semi-arid regions. In Africa about 25 million hectares of land is salt affected, with different degrees of degradation.

The main causes for the development of salinity and alkalinity in soils are:

i) use of saline irrigation water

ii) deposition of salts on soil surface from high sub soil water table

iii) seepage from the canals

iv) arid climate

v) poor drainage, and

vi) back-water flow or intrusion of sea water in coastal areas.

All these factors, either singly or in association with other factors, are responsible for the development of saline and alkaline soils in different parts of the world.

The major processes involved in the development of soil salinity in irrigated areas are transpiration, evaporation, and poor drainage. The salt problem before irrigation, and its extent, and management practices during irrigation are equally important factors (Micheal et al, 1978).

2.2 ORIGIN OF SALTS IN IRRIGATION WATER

The weathering of parent material of soil or rocks, which includes hydrolysis, hydration, solution, oxidation and carbonation, is the primary source of salts in irrigation water.

The weatherability of a mineral depends on the basicity of the mineral, degree of linkage of tetrahydrous in the clay mineral structure and the degree of crystallinity and purity of the mineral. Generally, weathering is governed by one or more of the above factors (Micheal et al, 1978).

2.2 CAUSES OF SALT ACCUMULATION

Saline or alkali soils are seldom formed in situ by residual weathering of primary rocks. On the other hand, hydrological conditions contribute substantially to the development of soil salinity and alkalinity. The hydrological processes release the salt constituents from the primary and secondary minerals to the surrounding waters. In arid regions, due to high evaporative conditions salt concentration is gradually increased in the water sources. (Micheal et al, 1978)

In humid regions, salts thus released are transported to lower layers and ultimately by streams to the ocean. Moreover, the salts deposited by irrigation, are leached down to lower layers of the soil by rainfall.

On the contrary, in arid regions the released salts may not be transported far away because of insufficient rainfall and whatever leaching of salts may occur, it would mostly be local.

However, high evaporating conditions of the arid regions tend to decrease further the limited available ground water for leaching the salts, moreover, the salts which move down due to rain, come back again to the surface by capillary action during the hot season.

2.4 EFFECT OF IRRIGATION, SOIL MANAGEMENT AND CROP MANAGEMENT ON SOIL SALINITY AND ALKALINITY

The nature and extend of salt accumulation and the degree of soil alkalinity depend on the quality of irrigation water, frequency of irrigation, soil type and its permeability, salt tolerance characteristics of the plants and climatic conditions.

Generally, soils of light texture are less salinized than those of medium and heavy textured soils. The soils irrigated with waters having the same concentration of salts develop more alkalinity with waters having higher proportion of sodium and bicarbonate ions. The presence of a hard pan of lime or clay further enhances the degree of alkalinity. The situation becomes more complex to predict when the depth of water table is high and the quality of irrigation water is poor. Under such situations, the final salt balance near the root zone is governed by the combined effect of the quality of irrigation water, irrigation management, climate and water transmission properties of the soil during the cropping period.

The salt accumulation is associated with the relief of the land. In flood plains, deltas, coastal belts and in areas of high water table, the salt concentration is usually high. In such a situation, surface runoff is low and the drainage water evaporates, leaving the salts on the surface. In areas of high water table, salts move up under thermal gradient and are deposited on the surface. Saline ground water and high water table are factors favouring soil salinity. However, the rate of salinization by capillary action decreases when the depth of water table is low, say beyond 1.5 meters and the soil moisture content is also low, Figure 1.0.

During irrigation, large volumes of water percolates down to lower layers, as a result of which the depth to ground water move up by capillary and are deposited on the surface as a result of both evaporation and transpiration.

In addition to the above factors, salinity and alkalinity problems develop in areas where drainage facilities are adequate but irrigation is insufficient to meet both the crops need and leaching requirement of the soil. Inadequate drainage is another factor intimately associated with the development of soil salinity.

Sometimes, in spite of good quality irrigation water and good irrigation practices, soil salinity develops because of the poor physical conditions which impede drainage.

2.5 IMPACT OF WATER QUALITY ON CROP PRODUCTION

Some low quality waters are characterized with high salt content and therefore with the increased probabilities of creating soil, water and crop problems. High sodium in irrigation water may reduce plant growth due to reduced soil permeability and aeration. The nutrients in treated waste water provide fertilizer value, but where plant needs are exceeded, may cause growth problems, use of primary-treated domestic waste effluents often causes clogging in sprinkler and particularly drip systems. (Grid Sefwat et al, 2000).

2.6 QUALITY OF IRRIGATION WATER

Whatever may be the source of irrigation water, viz, river, canal, tank, open well or tube well, some soluble salts are always dissolved in it. However, the nature and quantity of dissolved salts depends upon the source of water and its course before use.

The main soluble constituents in water are calcium, magnesium, sodium and sometimes potassium as cations and chloride, sulphate, bicarbonate and sometimes carbonate as anions. However, ions of some other elements such as lithium, silicon, bromine, iodine, copper, nickel, cobalt, fluorine, boron, zirconium, titanium, vanadium, barium, rubidium, ceasium, arsonic, antimony, bismuth, beryllium, chromium, manganese, lead, molybdenum, selenium and phosphate, and organic matter, are present in minor quantities.

These elements usually do not affect the quality of irrigation water as far as total salt concentration is concerned, but some ions as selenium, molybdenum and fluorine, if absorbed by plants in excessive amounts may prove harmful to the animal life when taken by them through drinking water, feed or forage. Among the soluble constituents, calcium magnesium, sodium chloride, sulphate and bicarbonate, and boron are of prime importance in determining the quality of irrigation water and its suitability for irrigation purposes. However, other factors as texture, structure of the soil, its drainage characteristics, nature of the crop grown and climatological conditions are equally important in determining the suitability of irrigation water in agriculture (Micheal et al, 1978).

The suitability of a water for irrigation will be determined by the amount and kind of salts present.

With poor water quality, various soil and cropping problems can be expected to develop. Special management practices may then be required to maintain full crop productivity.

The following are the most common problems that result from poor quality irrigation water:

i) **Salinity**: A salinity problem related to water quality occurs if the total quantity of salts in the irrigation water is high enough for the salts to accumulate in the crop root zone to the extent that yields are affected. If excessive quantities of soluble salts accumulate in the root zone, the crop has difficulty in extracting enough water uptake by the plant solution. This reduced water uptake by the plant usually results in slow or reduced growth.

ii) **Permeability**: A permeability problem related to water quality occurs when the rate of water infiltration into and through the soil is reduced by the effect of specific salts or lack of salts in the water to such an extent that the crop is not adequately supplied with water and yield is reduced. The poor soil permeability makes it more difficult to supply the crop with water and may greatly add to cropping difficulties through crushing of seedbeds, waterlogging of surface soil and accompanying disease, salinity, weed, oxygen and nutritional problems. It is evaluated first, from total salts in the water, since low salt water can result in poor soil permeability. Further, carbonates and bicarbonates can influence soil permeability.

The adverse influence of sodium on soil permeability has been recognized since long. But in many cases the evaluation of sodium influence alone has been found to be incorrect. This is because the long term influence of water on soil permeability depends on the interaction of:

1) Sodium content relative to calcium and magnesium;
2) Bicarbonate and carbonate content, and
3) the total salt concentration of water.

iii) **Toxicity:** A toxicity problem occurs when certain constituents in the water are taken up by the crop and accumulate in another that result in reduced yield. This is usually related to one or more specific ions in the water, namely, boron, chloride and sodium.

iv) **Miscellaneous:** Various other problems related to irrigation water quality occur with sufficient frequency and should be specifically noted. These include excessive vegetative growth, logging and delayed crop maturity resulting from excessive nitrogen in the water supply, white deposits on fruits or leaves due to sprinkler irrigation with high bicarbonate water and abnormalities indicated by an unusual pH of the irrigation water.

2.6 CHEMISTRY OF SALT AFFECTED SOILS:

The main processes occurring in soils while irrigating with poor quality waters are:

i) ion exchange between cations in irrigation water and those present on the soil exchange complex.

ii) Dissolution and precipitation of $CaCO_3$

iii) Weathering of minerals

iv) Hydration of the soil as a result of fluctuation in soil moisture;

v) Leaching down of ions

vi) Upward movement of ions through capillary activity and;

vii) Mineral nutritional characteristics of the crop grown.

Amongst these processes, cation exchange is the most important process, which governs the accumulation of excessive sodium during irrigation with saline water and reclamation of alkali soils during treatment with gypsium (Micheal et al., 1978).

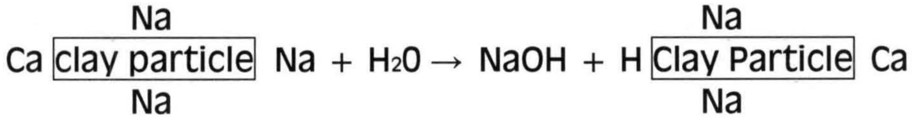
The finest fractons of soil particles, called clay, have a certain charge deficit. This charge is balanced by the charge of the adsorbed cation taken from the soil solution. These adsorbed ions on the clay phase are replaceable by any other cation. However, the rate of reaction depends upon its chemical affinity to the soil, its valency and size. These replaceable ions are called exchangeable cations. The maximum adsorption capacity of the soil for cations is called cation exchange capacity, which is generally expressed as meq/100 gm K soil. An order of replaceability of any ion present on the soil can be expressed as

$NH_4^+ > Mg^{++} > Ca^{++} > K^+ > Na^+$

This means that Ca^{++} will replace Na from the exchange complex more easily, while the replacement of Ca^{++} by Na^{++} is more difficult.

In normal soils, generally, Ca, Mg, K and NH_4 constitute 70, 25, 3 and 2 percent respectively, of the exchangeable cations. Such soils are dominated by Ca followed by Mg, K and NH_4. But in case of alkali soils the proportion of exchangeable Na is more and increases with the pH of soil. The pH of alkali soils generally increases with the degree of Na saturation. Exchangeable sodium percent (ESP) value of the soil is further influenced by the nature of the anion associated with the sodium salt in the solution phase.

A clay particle with sodium and calcium ions attached tends to hydrolyze. When a sodium ion is exchanged for a hydrogen ion, and the sodium ion combines with a molecule of water, sodium hydroxide (NaOH) is formed.

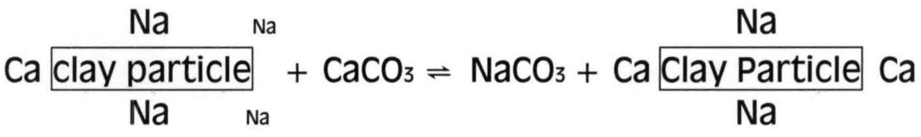


$$\mathrm{Ca}\,\overset{\mathrm{Na}}{\underset{\mathrm{Na}}{\boxed{\text{clay particle}}}}\,\mathrm{Na} + \mathrm{H_20} \rightarrow \mathrm{NaOH} + \mathrm{H}\,\overset{\mathrm{Na}}{\underset{\mathrm{Na}}{\boxed{\text{Clay Particle}}}}\,\mathrm{Ca}$$

When carbon dioxide (CO_2) is present in the soil air, it readily reacts with the water to form hydrogen carbonate (H_2CO_3) to form sodium carbonate ($NaCO_3$). $H_2CO_3 + 2NaOH \rightleftharpoons NaCO_3 + 2H_2O$

The Na_2CO_3 is gradually removed with extensive leaching, and the soil is left with hydrogen ions having replaced sodium ions. This increase of hydrogen ions is reflected in a lower pH.

Where soils contains calcium carbonate (CaCo3) or gypsium, calcium is dissolved into the soil solution. This available calcium is exchanged for sodium during the leaching process to obtain a normal soil.



$$\mathrm{Ca}\,\underset{\mathrm{Na}\qquad{\scriptstyle \mathrm{Na}}}{\overset{\mathrm{Na}\qquad{\scriptstyle \mathrm{Na}}}{\boxed{\text{clay particle}}}} + CaCO_3 \rightleftharpoons NaCO_3 + \mathrm{Ca}\,\underset{\mathrm{Na}}{\overset{\mathrm{Na}}{\boxed{\text{Clay Particle}}}}\,\mathrm{Ca}$$

2.7.1 **CHEMICAL PROPERTIES**:

Salinity hazard: When the salt distribution in the soil profile becomes excessive, crop growth is deteriorated. Such soils are often recognized by the presence of a white surface crust. In saline water irrigated areas, particularly in arid regions of Rajasthan, the EC of the Saturation extract of the soils is usually about three times and even more than that of irrigation water. In general, salt concentration is maximum on the surface and decreases with the increase in depth. (Table 2).

TABLE 2: EFFECT OF SALINE IRRIGATION WATERS ON SOIL PROPERTIES

Depth Cm	PH	EC Mmhos/cm	Exchangeable cations, meq/100 gm soil			CEC Meq/100gm soil	ESP	Textural class
			Na$^+$	K$^+$	Ca^{++} + Mg^{++}			
Nimlhara, Bhilwara., Rajasthan, irrigated with EC 5.5 mmhos/cm, SAR = 16.8								
0-15	8.3	19.2	13.0	0.45	10.3	23.7	54.8	Clay loam
15-38	8.4	18.1	12.0	0.32	10.0	22.3	53.5	Clay loam
38-60	8.7	16.2	12.0	0.28	10.1	22.4	53.5	Clay loam
60-85	8.3	11.9	13.0	0.14	9.1	22.2	58.5	Clay loam
>85	8.5	9.6	7.5	0.09	11.5	19.1	39.3	Clay loam
Salera, Bhilwara distt., EC=1.656 mmhos/cm, SAR = 15.7								
0-17	9.2	6.0	14.8	0.61	12.71	28.1	52.6	Sandy clay loam
17-35	9.0	6.5	18.2	0.53	15.71	33.9	53.8	Sandy clay loam
35-54	8.9	7.0	17.0	0.51	16.73	34.8	51.4	Sandy clay loam
54-73	8.8	7.0	15.7	0.38	15.12	31.2	50.3	Sandy loam
73-88	8.8	6.2	8.1	0.20	14.26	22.6	36.0	Sandy loam

Maliwal (1968), Mehta (1970)

In irrigated soils, the extent of salinity is more related to the process of salt water movement within the soil column than whether the salts are moving downwards with the leaching effect of irrigation water or are moving up by capillarity under the thermal gradient. In a well drained light textured soil immediately after irrigation, the soil salinity, as measured on the basis of saturation extract of the soil sample, would be less at surface layers and it would be more at deeper layers. On the contrary, in heavy soils accumulation of salts would always be more on the surface due to impeded drainage. Quantitatively, under similar soil water conditions, more salinity would be observed in arid than in humid regions and in heavy textured soils than in light soils.

2.7.2 **SODIUM HAZARD**:

In irrigated soils, the cations present in irrigation water as soluble salts, take part in an exchange reaction with the soil. The main cation exchange which takes place in between sodium ions in the irrigation water and calcium ion in the exchange complex of the soil.

$$\mathrm{Ca}\,\overset{\mathrm{Na}}{\boxed{\text{clay particle}}}\;\mathrm{Ca} + 2\mathrm{Na} \rightleftharpoons \mathrm{Ca}\,\overset{\mathrm{Na}}{\boxed{\text{Clay Particle}}}\;\mathrm{Na} + \mathrm{Ca}^{++}$$

According to this process a soil may or may not be changed into an alkali soil, depending upon the relative proportion of sodium and calcium ions in the equilibrium solution. However, the process of alkalization could be quick and can come to an equilibrium condition if the relative proportion of Na : Ca + Mg, as expressed by the sodium adsorption ratio, is high. The exchangeable sodium percentage increases with the total salt concentration and /or SAR of irrigation water or soil solution.

In arid and semi-arid regions, as the soil solution becomes concentrated through evaporation or transpiration, the solubility limits of calcium carbonate and magnesium carbonate are exceeded. As a result of this they are precipitated with a corresponding increase in the relative proportion of sodium in the soil solution. Hence, a part of exchangeable calcium and magnesium is replaced by sodium, increasing the sodium content. This leads to the conclusion that any chemical process in the soil, causing a decrease in calcium, either in solution or exchange phase, will lead to enhancement of alkalinity (Micheal et al, 1978).

In addition to the above process, the extent of degree of sodium saturation will be governed by the chemical affinity of the ion to the soil, its replacing power in comparison to other ions and its own replaceability by other ions. Fortunately, amongst sodium calcium and magnesium, the replacing power both of calcium and magnesium and their chemical affinity to soil are more than sodium. Hence, a higher proportion of sodium is necessary in the soil solution to replace calcium. The proportion of sodium to calcium and magnesium should be above 50 percent in the soil solution before it is adsorbed in significant amounts. Moreover, more Na is adsorbed at the same salt concentration and the same Na content when Mg is present rather than Ca, as the replaceability of Mg is more than that of Ca. It may be summarized that the process of alkalization and its extent is influenced by the total salt concentration, ionic composition, relative proportion of sodium to other cations, nature and total amount of clay and their ion exchange characteristics.

2.7.3 **MAGNESIUM HAZARD**:

Sometimes more magnesium is present in irrigation water than calcium. This increases the degree of magnesium saturation which also deteriorates the soil structure. Irrigation waters having relatively more magnesium than calcium are likely to decrease soil productivity. About 73 percent of the 4162 samples of poor quality well waters of Rajasthan were observed to have more mg than Ca (Paliwal, 1972).

2.8 **LEACHING REQUIREMENT**:

Leaching is a process of dissolving and transporting salts by downward movement of water through the soil. The leaching of soluble salts from the root zone is essential in irrigated soils. When the soils are highly saline, or irrigated with saline water, some more water is to be added to leach out the excessive salts or to avoid accumulation of salts.

Without leaching, salts accumulate in direct proportion to the salt content of the irrigation water and the depth of water applied. The concentration of salts in the soil solution results principally from the extraction of moisture from the soil by the process of evaporation and transportation. The depth of irrigation water per unit depth of soil, salinity for any given conductivity of irrigation water can be calculated from the following equation:

$$\frac{Di}{Ds} = \frac{ds}{dw} \cdot \frac{SP}{100} . \frac{DEC}{EC;} \ldots\ldots\ldots\ldots (i)$$

Where:

Di = depth of irrigation water

Ds = depth of soil

ds = density of soil (bulk density)

dw = density of irrigation water

Sp = Saturation percentage of the soil

ΔEC_e = Increase in electrical conductivity of Saturation Extract of the soil

ECW = Electrical Conductivity of Irrigation water.

Under high water table conditions, the increase in soil salinity by the evaporation of ground water can be determined by the following formula:

$$\Delta EC_e = \frac{Dg}{Ds} . \frac{Ecg}{Sp} . \frac{Dw}{ds} .100 \ldots\ldots\ldots\ldots\ldots\text{(ii)}$$

Where:

Dg = depth of ground water evaporated.

ECg = electrical conductivity of ground water

All other terms are as defined in equation (i). It may be noted that equation (ii) is obtained from the relationship expressed in equation (i), after substituting the depth of ground water evaporated and its EC for the depth of irrigation water and its quality.

The fraction of irrigation water that must be leached through the root zone to keep the salinity of the soil below a specific limit is termed as leaching requirement (LR). Mathematically it can be expressed as:

$$LR = \frac{Dd}{Di} = \frac{ECi}{ECd} \ldots\ldots\ldots\ldots\ldots \text{(iii)}$$

In which,

LR = leaching reaching requirement, expressed as a ratio or per cent.

ECi = Electrical conductivity of irrigation water, mmhos/cm

ECd = electrical conductivity of drainage water, mmhos/cm

Information on the consumptive use of water by the crop is necessary if the leaching requirement concept is to be used for determining either the depth of irrigation water that must be applied or the minimum depth of water to be drained, in order to keep the soil salinity from exceeding a specified value. The depth of irrigation water Di by the equation.

$$Di = Dc + Dd \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(v)}$$

Using equation (1) to eliminate Dd from equation (ii)

$$Di = \frac{Dc}{1-LR}$$

Expressing the leaching requirement (LR) in equation (v) in terms of the EC ratio of irrigation and drainage waters, as given in equation (vii), provides the following relationship.

$$D_i = \left[\frac{EC_d}{EC_d - EC_i}\right] D_c \quad \ldots\ldots\ldots\ldots\ldots \text{(vi)}$$

Equation (vi) gives the relationship in terms of the depth of water lost by evapo-transpiration and the salt concentration of irrigation water which is required to satisfy both the evapo-transpiration and leaching requirements of the soil. Of the factors, EC_i is known from chemical analysis of the irrigation water and EC_d is taken on the basis of permissible salt tolerance limits of the crop. But generally, saturation extract of the soil solution (EC_e). In most cases EC_d is assumed to be approximately twice as high as the corresponding EC_e (Micheal et al., 1978).

2.9 DRAINAGE OF IRRIGATED LAND IN RELATION TO SALINITY CONTROL:

Drainage in Agriculture is the process of removal of excess water from soil. In arid and semi-arid regions, suitable drainage systems are essential for adequate control of soil salinity. This includes both the adequacy of drainage and the quantity of water to be drained. The first factor is more related to the control of water table, preferably at about 1.5 metres below the soil surface, so as to maintain a favourable salt balance near the root zone during the cropping period. While irrigating with saline water, if the water table rises to within 60cm to 1 metre from the surface, lands often go out of cultivation because of the rapid accumulation of salts in the root zone. Hence the depth of water table should be kept such that roots are beyond the zone of capillary action (Micheal et al, 1978).

Salinity can be control by applying requisite amounts of water according to the leaching requirement of the soil. But water and the salts dissolved in it will be able to move downwards only when the water table is low. In irrigated areas the problems of high and fluctuating water tables and salinity occur simultaneously in a particular region. Hence, the drainage system of the entire area is to be planned, as a single unit, rather than for a particular field. The drainage programme for irrigated land should be initiated and continuously integrated with the development of the irrigation system in order to attain an efficient overall water and salinity control programme.

High water table can be lowered by preventing excessive seepage from canals, efficient water use on the farm and by providing artificial drainage systems in areas where there is inadequate natural drainage. Frequent irrigations with small amounts of water or sprinkler irrigation may help in increasing the efficiency of water use in areas of high water table. If the ground water is of good quality it could be pumped from a high water table area and used in needy areas (Micheal et al, 1978).

2.9.0 IMPROVEMENT OF WATER QUALITY:

The harmful effect of irrigation water can be minimized to some extent by modifying its ionic composition by adding such chemicals which tend to precipitate the harmful constituents such as bicarbonate and carbonate in form of less soluble salts or tend to create a favourable cationic (Ca:Mg:Na) ratio. There appears to be no technique to reduce the total salt concentration of irrigation water for large irrigation projects except by diluting it or mixing with good quality water, if available nearby. If the water contains excessive amounts of sodium (>70% soluble sodium), bicarbonate (>8 meq/l) and Magnesium (as Mg:Ca ratio >4), such a sample is likely to be normally low in calcium content. An unfavourable proportion between calcium and sodium, whether caused by sodium alone or induced by bicarbonate or high Mg : Ca ratio, can be improved by adding a cheap and soluble source of calcium in the irrigation water. This is more essential because the lack of calcium below a critical level in the soil-water –plant system is more harmful than the excess of sodium in equivalent amounts.

Gypsium (hydrated calcium sulphate – $CaSO_4 . 2H_2O$), by virtue of its low (0.25% - 0.3%) solubility and cost is quite suitable for creating a favourable Ca : Na or Ca : Mg ratio in irrigation water. Improvement in Ca : Na ratio or SAR takes place by increasing the calcium ion concentration, decreasing Mg : Ca ratio and precipitating excessive carbonate ions.

$2NaHCO_3 + CaSO_4 \leftrightharpoons Ca(HCO_3)_2 + Na_2SO_4$

$Ca(HCO_3)_2 \leftrightharpoons CaCO_3 + H_2O + CO_2$

Success of gypsium application in irrigated wate or soil depends upon the choice of the grade of gypsium, its particle size, method of application and quantity applied. Large quantities of gypsium are available as deposits in Rajasthan near Bikaner, Rishikesh in U. P. and the State of Jammu and Kashmire all in India. Gypsium obtained from the mines is of different grades of purity, but, for agricultural purposes, gypsium above 65 percent purity is quite suitable. However, gypsium of higher grade is preferred for economic reasons.

For all practical purposes, gypsium should be powdered upto 0.5mm size or passed through a 30 mesh sieve. The gypsium requirement of water should be calculated, depending upon the relative concentration of sodium, magnesium and calcium ions in irrigation water and the solubility of gypsium. To add 1 meq/1 of calcium, 8.6 quintals of gypsium of 100 percent purity per hectare metre of water would be necessary. Hence, the actual amount of gypsium is to be calculated, depending upon the amount of calcium and water to be added for the crop in question. Mixing of gypsium directly in irrigation water poses some problems. If it is placed in bags or containers between the entry and outlet of water, it does not dissolve uniformly with increase of time, and most of it is deposited at the place of entry of water in the field and forms bigger granules from powdered gypsium on coming in contact with water. However, some of the above limitations can be overcome by applying its saturated solution by a mechanical device in the flowing water at a constant rate.

Since gypsium application improves both poor quality water and alkali soil, it is desirable to apply gypsium, both in the soil and in water, rather than treating water alone. But, if the soil is good and only the water is bad, gypsium should be applied only in water (Micheal et al., 1978).

2.9.1 CHOICE OF SALT TOLERANT CROPS:

Some crops and their varieties are more salt tolerant than others (Tables 3 and 4). Hence, salt tolerant crops are to be grown in salt affected areas till the soils are improved by vegetation or adopting other reclamation procedures.

2.9.2 **USE OF FERTILIZERS**:

Generally, saline and alkali soil or soils irrigated with poor quality waters are low in their fertility status, especially with reference to nitrogen or sometimes to phosphorus. Better crops can be grown by raising their fertility status, Nitrogen response to crops is better when it is applied to soil along with manures. It has been observed that for wheat, barley and maize, the usual doses of fertilizers, as applied on normal soils, can be applied upto an EC value of 6.5 millmhos/cm and an exchangeable sodium per cent of about 30. However, excessive fertilization or addition of fertilizers, on a highly saline alkali soil, is of no value.

Amongst the fertilizers, nitrogen is better than phosphorus followed by potash. However, up to moderate levels of salinity and alkalinity, phosphorus and potash, application may be profitable only in the presence of nitrogen. Application of urea should be avoided due to its higher rate of nitrogen loss in the gaseous form under saline-alkali conditions.

The efficiency of fertilizers on soils irrigated largely with saline water or salt – affected soils depends largely on the interactive effects of salts, exchangeable sodium and fertilizers. The most important determining factors are the nature and degree of salinity and sodicity, chemical reactivity and solubility of added fertilizers, nutrient requirement of the crops, their availability in the soils and the salt tolerance behaviour of crops. This indicates that in salt affected soils, the behaviour of fertilizers is quite complex and efficiency of fertilizers in such soils has to be evaluated keeping in view, the quality of irrigation water, level of soil salinity and sodicity and their interactive effects.

2.9.3 SOIL MANAGEMENT PRACTICE

In order to adopt irrigation with poor quality water on a long term basis, it is of utmost importance to have the detailed analysis of representative profiles for their physical, chemical and morphological characteristics. Soil analysis should include its texture, structure, pH, lime content, location and amount of gypsium, (if present in the profile). Total soluble salts, their ionic composition and exchangeable cations. Gypsium requirement is to be estimated if the soil is highly sodic. Information on water transmission properties of the soil and depth of water table are to be obtained. Data on the climatic parameters as amount of rainfall, its intensity, distribution, and evaporation are to be obtained, as these control the periodic as well as annual salt build-up in an irrigated areas.

Accumulation of excessive amount of salt and development of high sodicity are the main limitations in the safe utilization of poor quality irrigation water. These depend upon the nature and amount of clay minerals in the soil and the quality of irrigation water. Success of irrigation with saline water lies on the degree of accuracy in the predicted values of soil salinity and sodicity expected to be developed during the cropping period. Saline waters can more safely be used in coarse than in fine textured soils.

A field infected with the problem of salinity should be levelled carefully. This will help in uniform spread of water and facilitate its downward movement, otherwise, at high spots (if salts are not leached) it will lead to salt accumulation and will cause heterogeneity in salt concentration. (Micheal et al, 1978). Application of gypsium under conditions of low water table may further improve land productivity. The success of gypsium or flushing of salts lies in the drainability of the soil. Hence, if the improvement of internal drainage by tile drains is too economically feasible, attempts should be made to improve soil physical conditions by using fertilizers and manures in combination. This could be supplemented by improving the surface drainage system.

2.9.4 **IRRIGATION MANAGEMENT:**

While irrigating with poor quality waters, accumulation of salts increases with the fineness of soil texture. Since concentration of salts in the soil solution near the root zone determines the degree of adverse effects on crop growth, rather than the salt concentration of irrigation water alone, it is essential to adopt irrigation practices such that the salinity at the root zone is kept to the minimum. For this purpose, the quantity of water and the frequency of irrigation are also kept that they could meet the leaching requirement of the soil and the consumptive use of the crops grown.

Salts often accumulate in the top few centimeters of the soil during non-crop periods. Where high water tables complicate salinity control, fallow and idle lands may rapidly accumulate surface salts particularly in hot arid climates. Under such conditions, both crop germination and yield can be seriously reduced. A heavy pre-sowing irrigation to leach these surface salts will improve germination and early growth and is sometimes an essential practice. It is made far enough in advance of the desired planting date allow for cultivation to remove weeds and prepare the seedbed.

2.9.5 **PLANT RESPONSE TO SALINE AND ALKALI SOILS:**

Excessive salinity usually causes poor stands of crop, stunted growth and reduced yield. It may also cause leaf burns in some crops and deep blue-green colour in others. In some cases symptoms of excessive salts are similar to those of drought or low fertility status. Soil salinity causes a decrease in the size and vigour of the plant. The germination of seeds is delayed and retarded but the cropping period is slightly reduced with the increase of salinity. However, its effects on the yield and quality of the crop are variable. In general, grain yield is affected more than the height of the plant.

2.9.6 **EFFECT OF SALTS ON PLANT GROWTH:**

Excessive soil salinity and alkalinity may adversely affect plant growth by:

i) Increasing the osmotic pressure in the soil solution;

ii) Accumulating certain ions in toxic concentration in the plant tissue, and

iii) By altering the plants mineral nutritional characteristics.

2.9.7 SALT TOLERANCE CROPS:

Salt tolerance means the ability of a plant to tolerate salt concentrations in the root zone. A knowledge of the salt tolerance characteristics of a crop is important to selecting a particular crop or its variety to suit the soil conditions and for determining the leaching requirement.

The effect of soil salinity on crop growth is negligible when the electrical conductivity of the saturation extract (Ec_e) is less than 2 mmhos/cm. Yields of very sensitive crops are reduced when the Ece value is about 4 mmhos/cm. Many of the common field crops are affected when the Ec_e value is in the range of 4 to 8 mmhos/cm. Crops with high salt tolerance can grow satisfactorily when the Ec_e values are between 8 and 16 mmhos/cm. Only a few crops survive at Ec_e value beyond 16 mmhos/cm.

Table 2.5 presents the salt tolerance characteristics of some of the common crops, which are listed in decreasing order of tolerance with each group. The salt resistant varieties of some of the important field crops are presented in table 2.6.

Table 2.6: Salt resistant Varieties of some important field crops

Crop	Varieties
Rice (Oryza sativa	Jaya, IRS-68, IR-8, Pusa 2-21; Padma*
Wheat (Triticum aestivum)	K-65, Sonalika, Hira* WG 357, HD 2177, HD 2181-1, HD-2238, Kalyansona, IWP 502*
Barley (Hordeum vulgare)	RS-6, Jyoti, DL-3 Ratna*
Pea (Pissum sativum)	Bounewille**
Rai (Brassica juncea)	RS-3, Pillibhit* Varuna, Harmana-1, Sulphala**
Safflower (Carthamus tinctorius)	N-18, US 10*
Sugarbeet (Beta vulgaris)	Erotype E, Margo Magnopoly, Kawe Gigapoly*
Sorghum (Sorghum vulgare	SP-771, SP-146, 8942 (folder).&
Bajra (Pennisetum typhoidus)	IP-68, Syn-3, Syn-2*
Cotton (Gossipium Hirsutum)	Atala-1517, Acala P-18*
Sugarcane (Sacchrum Officinarum)	CO 205; CO 286, CO 280, POJ 2878, CO 975 B 37-172*

Compiled by Paliwal and Yadav (1976)

* Central Soil Salinity Research Institute, Karnal, Proc. Summer Instt., 1973

** Water Technology Centre, IARI, New Delhi.

These limits, however, are variable with respect to climatic conditions soil fertility level, irrigation management, crop variety and soil type. In some crops, the salt tolerance limit varies with the stage of growth. For example, rice is quite tolerant during germination but becomes sensitive during seedling stage. Similarly, maize is more tolerant during germination than at later stages of growth. On the other hand, sugarbeet can tolerate salinity only up to 4 mmhos/cm during germination but can sustain itself at much higher levels of salinity after the seedlings are established.

Table 2.5: Relative salt tolerance of crops

Tolerant	**Semi-Tolerant**	**Sensitive**
	Field Crops	
Barley	Oats	Field Beans
Dhaincha (Serbania acculenta	Rice	Gram (Channa
Sugarbeet	Sorghum (jowar)	Peas (mutter)
Tobacco	Pearl millet (bajra)	
Turnips	Maize	
Mustard	Red gram (Arhar)	
Cotton	Green gram (Mung)	
Wheat (Kalyan Sona)	Sunflower	
Sugarcane	Castor	
Taramira	Sesamum	
	Linseed	
	Fodder Crops	
Saltbush	Turnips (Senji)	
Dub grass	Sudan Grass	Guar
Rhodes grass	Lucerne	
	Metha	
	Sorghum (Jowar)	
	Maize	
	Berseem	
	Cowpea (lobia)	
	Vegetables	
Turnips	Tomato	Celery
Beet-root	Cabbage	Green beans
Asparagus	Cauliflower	
Spinach	Luttuce	
	Potato	
	Carrot	
	Onion	
	Pea	
	Cucumber	
	Bitter gourd (Karela)	
	Fruits.	
Date Palm	Pomegranate	
Coconut	Grape	
	Guava	
	Mango	
	Banana	
	Pear	
	Apple	
	Orange	
	Grape fruit	
	Plum	
	Almond	
	Apricot	
	Peach	
	Strawberry	
	Lemon	

2.9.8 BORON TOLERANCE OF CROPS

Boron, though essential for plant growth, becomes toxic beyond a concentration of a few ppm. It does not seem to affect the germination of seeds up to 20 ppm or even more, but the growth rate and height of seedlings are significantly reduced beyond 1 or 2 ppm. Relatively, legumes are salt sensitive but can tolerate more boron than cereals. Amongst field crops, wheat and barley can tolerate from 1 to 2ppm of boron in irrigation water.

Boron is translocated in the leaves and accumulated in the tip and margin. Toxicity symptoms such as yellowing and tip burn are usually visible. If boron toxicity is indicated in the plant its source should be found. If irrigation water has excessive boron, it should be mixed with good quality water and if soil is the cause, the boron should be reduced by leaching, though its leaching is more difficult than of salts. Table below shows in decreasing order the boron tolerance of some of the crops.

Table 2.7 **Limits of Boron in Irrigation Waters for Crops of different degree of tolerance**

Tolerant	Semi-Tolerant	Sensitive
	3.0 ppm	1.0 ppm
4.0 ppm	Sunflower	Plum
palm (Phoenix Canariensis	Potato	Pear
Date Palm	Cotton	Apple
Sugarbeet	Tomato	Grape
Lucern	Raddish	Cherry
Broddbean	Pea	Peach
Onion	Barley	Appricot
Turnip	Wheat	Orange
Cabbage	Maize	Grape Fruit
Lettuce	Oat	Lemon
Carrot	Pumpkin	
	Sweet Potato	
2.0 ppm	1.0 ppm	0.3 ppm

Adapted from Wilcox (1960)

2.9.9 **RECLAMATION OF SALINE SOILS**:

The reclamation of a saline soil depends on the efficiency of removal of salts from the upper to lower layers and is thus relatively simple if drainage is not restricted. The simplest procedure is to flood the field after making ridges or leeves at the boundaries. The movement of water through the soil profile will carry the dissolved salts into the lower layers below the root zone. These salts are drained away if adequate sub-surface drainage is provided.

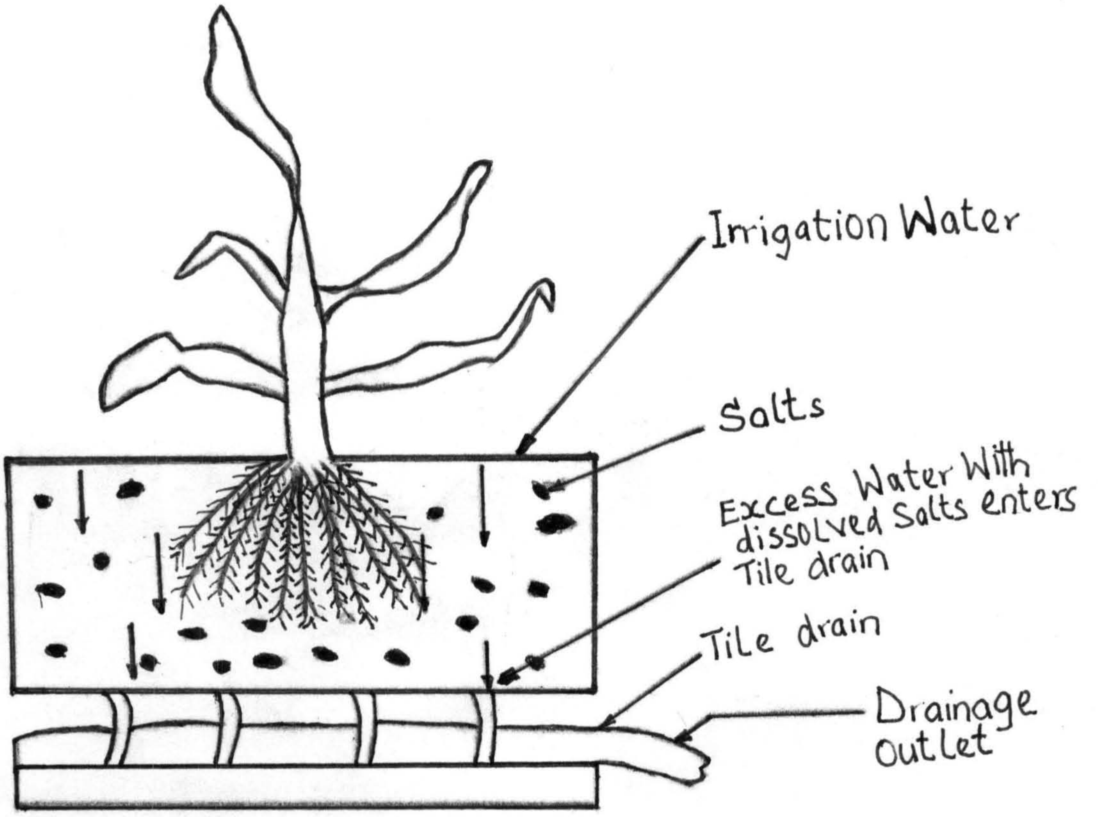


Fig. **Schematic Sketch illustrating the role of tile drain in controlling waterlogging and salt accumulation**

The quantity of water needed for leaching depends mainly on the severity of the salinity problem and the depth and degree of the reclamation desired. The efficiency of the reclamation per unit volume of water will be maximum with good water. The lower the salt content in the irrigation water, the greater is the efficiency in reclaiming saline soils.

In practice, where water is inadequate or the soils are slowly permeable, it is desirable to obtain partial reclamation and then a more salt tolerant crop like barley could be grown.

Leaching may be continued during the cropping period also. The effectiveness of leaching varies from soil to soil and depends largely on the quantity of water that passes through the soil. The rate of removal of salt is fast in the beginning but later on the process is slowed down.

The efficiency of leaching is also influenced by varying the water flow velocities within a soil. In light soils higher rate is favourable but in heavy soils intermittent flushing is better as the water gets adequate time to percolate slowly through the small soil pores.

2.9.1.1 **RECLAMATION OF ALKALI SOILS:**

The reclamation of alkali soils is more difficult than saline soils because alkali soils have a very low permeability and they require the replacement of excessive exchangeable sodium by calcium. It is necessary that the replaced Na ions are leached down to lower layers. The improvement of soil tilth is slow in alkali soils. Excessive exchangeable sodium can be replaced by any cheap source of calcium and magnesium salts such as calcium chloride, magnesium chloride and gypsium. Soluble calcium and magnesium salts are suitable for the reclamation of alkali soils. Of these salts, calcium and magnesium chlorides are quick in reaction but such soils. Green manuring adds soil organic matter and increases soil fertility. The effectiveness of dhaincha is due to the following characteristics:

i) It is tolerant to salts and waterlogging conditions;

ii) Its root system is extensive;

iii) It opens compact subsoil and improves soil permeability;

iv) Its rate of decomposition is fast, and

v) Its cell sap is acidic and is capable of neutralizing the alkalinity of the soil.

2.9.1.2 **RECLAMATION OF SALINE-ALKALI SOILS**:

When the soil is saline as well as alkali it is essential to leach out the excessive salts up to an EC value of 6 to 8 mmhos/cm before an attempt is made to remove excessive exchangeable sodium by gypsium. However, some excess salts can be leached by flooding the field after gypsium application, for removing the released sodium from the soil exchange phase.

Maintenance of an adequate drainage is essential for the successful reclamation of saline, alkali and saline-alkali soils, as leaching out of the salts or the removal of the reaction products is a must for the success of reclamation. In case the subsoil has lime or clay hard pan it should be broken by deep ploughing or sub-soiling.

2.9.1.3 **DEFINITIONS:**

2.9.1.4 **Alkali or sodic soil**:- A soil that contains sufficient exchangeable sodium to interfere with the growth of plants either with or without appreciable quantities of soluble salts. Tentatively, a limit of 15 percent of exchangeable sodium is taken as the lower limit for depending on alkali soil.

2.9.1.5 **Alkali soil**: A soil that has an alkaline reaction, i.e. a soil for which the pH of the saturated soil paste is higher than seven.

2.9.1.6 **Alkalinization**: The process whereby the exchangeable sodium content of a soil is increased.

2.9.1.7 **Cation exchange:** Interchange of a cation in solution with another cation on a surface-active material.

2.9.1.8 **Cation exchange capacity (CEC):** The total quantity of cations which a soil can absorb by cation exchange, usually expressed as milliequivalents per 100 grams.

Measured values of the cation exchange capacity depend somewhat on the method used for its determination.

2.9.1.9 **Dispersed Soil**: Soil in which the clay readily forms a colloid soil. Dispersed soils usually have low permeability. They tend to crack, shrink, and become hard on drying and become plastic on wetting.

2.9.2.0 **ELECTRICAL CONDUCTIVITY (EC)**: It is the reciprocal of the electrical resistivity. Quantitatively the electrical resistivity is the resistance, in ohms, of a conductor, metallic or electrolytic, which is one cm long and has a cross-sectional area of 1 sq. cm. Hence electrical conductivity is expressed as the reciprocal of ohm-cm or mhos per cm. The term "electrical conductivity" and specific electrical conductance have identical meanings. For convenience in units, millimhos/cm (10^{-3} mhos/cm) or micromhos/cm (10^{-6} mhos/cm) are used.

Symbol	**Term**	**Unit**
EC	Electrical conductivity	mhos/cm
Mmhos/cm	millimhos/cm	10^{-3}mhos/cm
Umhos/cm	micromhos/cm	10^{-6}mhos/cm

2.9.2.1 **Equivalent Weight**: It is the combining capacity of an element or radical with hydrogen. It is the weight in grams of an ion or compound that combines with or replaces one gram of hydrogen.

$$\text{Equivalent Weight} = \frac{\text{Atomic Weight}}{\text{Valency}}$$

For example,

Equivalent weight of $Na^+ = \frac{23}{1} = 23$, $Ca^{++} = \frac{40}{2} = 20$

$CL^- = \frac{35.5}{1} = 35.5$; and $SO_4 = \frac{96}{2} = 48$

$$\text{Milliequivalent Weight} = \frac{\text{Equivalent Weight}}{1000}$$

Equivalent Weights of some common salts and chemical amendments are given below: 1A table 1.0.

Table 2.7 **CHEMICAL SYMBOLS, EQUIVALENT WEIGHTS, AND COMMON NAMES OF SOIL COMMON SALTS AND CHEMICAL AMENDMENTS**

	Chemical Symbol Or formula	**Equivalent grams**	**Common Name**
Ions	Ca^{++}	20.04	Calcium
	Mg^{++}	12.16	Magnesium
	Na^+	23.00	Sodium
	K+	39.10	Potassium
	Cl^-	35.46	Chloride
	SO_4^-	48.03	Sulphate
	Co_3^-	30.00	Carbonate
	HCO_3^-	61.01	Bicarbonate

Salts

$CaCl_2$	55.50	Calcium chloride
$CaSO_4$	68.07	Calcium Sulphate
$CaSO_4\ 2H_2O$	86.09	Gypsium
$CaCO_3$	50.04	Calcium Carbonate
$MgCl_2$	47.62	Magnesium chloride
$MgSO_4$	60.19	Magnesium sulphate
$Mg\ CO_2$	42.16	Magnesium carbonate
$NaCl$	58.45	Sodium chloride
Na_2SO_4	71.03	Sodium sulphate
$NaCO_2$	53.00	Sodium carbonate
$NaHCO_3$	84.01	Sodium bicarbonate
KCl	74.56	Potassium chloride
K_2SO_4	87.13	Potassium sulphate
$K2CO_3$	69.10	Potassium carbonate
$KHCO_3$	100.11	Potassium bicarbonate

Chemical Amendments

S	16.03	Sulphur
H_2SO_4	49.04	Sulphuric acid
$Al_2(SO_4)_3.18H_2O$	111.07	Aluminium sulphate
$FeSO_4.7H_2O$	139.01	Iron Sulphate (Ferrous)

2.9.2.2 **Non-Saline alkali soil.** A soil which has exchangeable sodium percentage (ESP) above 15 and EC of the saturation extract less than 4 millimhos/cm. The pH value of such soils is more than 8.5 and ranges between 8.5 to 10.

2.9.2.3 **Parts per million (p.p.m):** The results of a chemical analysis of water are usually reported in parts per million of the various substances present in the sample. One parts per million (p.p.m) means one part in a million parts. As commonly measured and used, parts per million is numerically equivalent to miligrams per litres.

2.9.2.4 **SALINE-ALKALI SOIL**: A soil which shows EC of the saturation extract (Ec_e) more than 4 millimhos/cm at 25°C, and its ESP value is greater than 15. The pH of the saturated soil paste may somewhat exceed 8.5.

2.9.2.5 **SALINE SOIL**: A soil which shows electrical conductivity of the saturation extract (Ec_e) more than 4 millimhos/cm at 25°C, the exchangeable sodium percentage is less than 15 and the pH of the saturated paste is usually less than 8.5.

2.9.2.6 **SATURATION EXTRACT**: The solution extracted from a soil at its saturation percentage.

2.9.2.7 **SATURATION PERCENTAGE**: The mixture percentage of a saturated soil paste expressed on dry weight base.

2.9.2.8 **SODIUM ADSORPTION RATIO (SAR):** A ratio for soil extracts and irrigation waters used to express the activity of sodium ions in exchange reactions with soil.

$$\mathrm{SAR} = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 **SOIL ANALYSIS:** The soil samples before being sent to the analytical laboratory for analysis was treated as follows:

a) **Drying**: The samples were spread out and air-dried at room temperature for about 3 days

b) **Sieving:** Except for the samples meant for organic matter and total element analysis, the soil should be grounded to pass through 2-mm sieve and at least 400g of each soil should be sent. For organic matter and total element analyses, the samples should be ground to pass through 0.5-mm or 60-mesh sieve and about 100g sample should be sent from each soil. All samples were adequately labeled.

3.1 **Particle – Size Analysis: Bouyoucos method**:

Particle size (or mechanical) analysis is the determination of percent sand, silt and clay particles in the soil. The principle used in the determination is based on the fact that particles suspended in water settle differently depending on the amount of surface per unit volume. The rate at which they settle can be calculated using stoke's law. In the Bouyoucos or hydrometer method, the amount of particles in suspension is determined by using hydrometer to measure the density of the suspension at the appropriate settling times.

The method which is in general use in Highway Department Soil Testing Laboratories in the U.S.A. is simple and rapid. It is, however, not as accurate as the pipette method, in which a portion of the suspension is withdrawn by a pipette, evaporated, and the amount of soil material determined by weighing.

3.1.2 **APPARATUS**:

1. Multimix machine with baffled "milkshake" cups
2. Glass (Bouyoucos) cylinders approximately of one litre capacity.
3. Special hydrometers

4. Thermometers.
5. Sodium hexametaphosphate dispensing agent (Calgon) $Na_2(PO_3)_6$

3.1.3 PROCEDURE

1. Weigh 50g (oven dry) or 51g (air dry) of fine textured soil (or 100g of coarse textured soil and place in the baffled cup. Fill the cup ½ full with distilled water and add 50ml of neutral sodium hexametaphosphate.
2. Place cup on stirrer and stir until soil aggregates are broken down (6 minutes for sand, 10 minutes for light heavy sandy loams and 15 minutes for other soils).
3. Transfer suspension to a Bouyoucos cylinder and fill to the lower mark with distilled water while the hydrometer is in suspension (if 100g of soil are used, fill to the upper mark).
4. Determine percent sand in the sample as follows:
    a) Remove hydrometer and shake suspension vigorously. Place cylinder on desk and record the time. At the end of 20 seconds, carefully insert the hydrometer and read the hydrometer at the end of 40 seconds. Read the reading on the data sheet.

b) Remove the hydrometer from the suspension. Record the temperature of the suspension.

c) For each degree above 67°F, add 0.2 to the reading to get the corrected hydrometer reading. For each degree less than 67°F, subtract 0.2 from the reading. In the centigrade scale, add 0.3 unit for every degree above 20°C or subtract 0.3 for every degree below 20°C.

The hydrometer is calibrated so that the corrected reading gives the grams of soil material in suspension. The sand settles to the bottom of the cylinder within 40 seconds, therefore, the 40 second hydrometer reading actually gives the amount of silt and clay in suspension.

The weight of sand in the sample is obtained by subtracting the corrected hydrometer reading from the total weight of the sample. The percentage sand is weight of the sample and multiplying by 100.

5. Determine percent clay in the sample as follows:

Shake the suspension and take reading at the end of 2 hours. Insert hydrometer just before the reading is made.

Take the temperature of suspension and correct the reading as in 4C.

At the end of 2 hours, the silt in addition to the sand has settled out of suspension. The corrected hydrometer reading then represents the grams of clay in the sample. The percent clay is calculated by dividing this weight by the weight of the samples and multiplying by 100.

6. Calculate the percent silt in the sample;

   Find the percent silt by difference. Subtract the sum of the percentages of sand and clay from 100 to get the percent silt.

7. Determine the class name or texture of the soil from the textural triangle given.

3.2.0 SOIL pH DETERMINATION:

3.2.1 **Apparatus**:

Glass – electrode pH meter

3.2.2 Reagents:

1. Distilled water
2. 0.01M $CaCl_2$ (or IN KCL)

3.2.3 PROCEDURE

(A) **Soil pH in Water (1 : 1 Soil/Water ratio).**

1. Weigh 20g of air-dry soil into a 50-ml breaker. Add 20 ml of distilled water and allow it to stand for 30 minutes. Stir occasionally with a glass rod.
2. Insert the electrodes of the pH meter into the portly settled suspension and measure the pH. Do not stir the suspension during measurement.
3. Report result as "Soil pH measured in water".

(B) **Soil pH in 0.01M $CaCl_2$**

1. Use a 1:2 (Soil : 0.01m $Cacl_2$) suspension by adding 10g of soil to 20ml of solution.
2. Let the suspension stand for about 30 minutes and stir occasionally with glass rod.
3. Measure pH and report as "Soil pH measured in 0.01M $Cacl_2$".

(C) **Soil pH in IN Kcl (1 : 1 soil to Solution ratio, 30 minutes)**

Report as "Soil pH measured in IN KCL". Standardization of pH meter, use Buffer 4 and 7 or buffer 9, where there is no Buffer 7. But Buffer 7 was used.

3.3.0 CATION EXCHANGE:

The study of cation exchange in soils includes the determination of the following:

a) Cation – exchange capacity (CEC)

b) Total exchangeable bases (TEB)

c) Exchangeable acidity (EA)

(a) Cation exchange capacity is defined as the sum of exchangeable cations in soil, usually expressed as millequivalent (meq) per 100g of soil. Some exchangeable cations are more easily replaced than others, and hence the completeness of replacement of some cations will depend on the particular salt solution used. Thus a method for determining the CEC accurately for one soil may not work for other soil.

The standard method of determining CEC involves saturation of the exchange complex with a given cation and then determining the total of the adsorbed cations by the appropriate means.

The second approach which is regarded as being accurate for acid soils is to determine both exchangeable bases and exchangeable acidity since

$$CEC = TEB + EA.$$

The exchange acidity (EA) may be defined as total titratable acidity of the soil and represents the acidity due to exchangeable hydronium and aluminium ion.

The USDA soil taxonomy uses the summation method involving $\underline{N}$ NH_4 OA_c exchangeable bases plus $Bacl_2$ – TEA extractable "total acidity".

An alternative method which is used in tropical soils is the summation involving $\underline{N}$ NH_4 OA_c exchangeable bases plus the $\underline{N}$ KCL exchangeable acidity. The CEC determined in this way is referred to as "effective CEC". The magnitude of exchangeable acidity obtained by Bacl2 – TEA method is usually higher than the value obtained by $\underline{N}$ Kcl method.

The neutral $\underline{N}$ NH4 or Na – acetate displacement procedure is used in the FAO soil classification scheme.

3.3.1 Determination of Exchangeable Bases (TEB)

A. **Leaching Method**

Applicable to non-saline non-calcareous soils only.

3.3.2 Apparatus

NH_4 OAC, 1$\underline{N}$ (pH 7.0): Dissolve 77.08g NH4 OAc (Special grade for analysis) in water, cool, dilute to 1 litre and adjust to pH 7.0

using HOAc or NH_4 OH, or prepare it from glacial acetic acid and ammonia as described.

3.3.3 **PROCEDURE:**

1. Prepare leaching tube by pouring filter paper pulp on to perforated base, apply gentle suction and tamp down to farm filter pad.
2. Weigh 15g air-dry soil and mix with similar volume of coarse (2-4mm) silica. Transfer on to filter pad in leaching tube.
3. Invert 250 – ml volumeter flask neutral NH_4 OAc into the tube and control rate of leaching slow dropwise, with pinchcock on outlet.
4. When supply flask is empty apply gentle pressure from a blow ball to top of Leaching tube to free as much as possible the soil of liquid. Keep the residue for direct determination of CEC as described.
5. Transfer the leachate to a 250-ml volumetric flask and make up to the mark with water.
6. Determine K and Ca by flame photometers and Mg by atomic absorption spectro photometer. Calcium and Mg can also be determined by versenate titration.

3.3.2.3 BATCH METHOD:

3.3.2.4 Apparatus:

1. Centrifuge
2. 100-ml volumetric flask
3. Flame photomter (Na$^+$ & K$^+$)
4. Atomic absorption spectrophotometer, Ca & Mg titration method.

3.3.2.5 Reagents:

1. Acetic acid, glacial and NH_4 OH, conc.
2. Ammonium Acetate solution, 1N. pH 7.0 – Add 58 ml of glacial acetic acid to about 600 ml of distilled water in a 2 litre beaker.

Add 70 ml concentrated NH_4 OH (specific gravity 0.90). The NH4 OH is best added under a fume hood through a long -- stemmed glass funnel so that it is introduced into the bottom of the acid solution. Cool this solution and adjust to pH 7.0 with acetic acid or NH_4 OH using a pH meter. Transfer the solution into a 1 litre volumetric flask and dilute to volume. Mix it and store in a pyrex reagent bottle.

3.3.2.6 **PROCEDURE**:

1. To 5g of soil sample in a 50-ml centrifuge tube, add 30ml of 1 N NH_4 OAc and shake it on a mechanical shaker for 2 hours.
2. Centrifuge (2000 r.p.m. for 5 – 10 minutes). Carefully decant the clear supernatant into a 100-ml volumetric flask.
3. Add another 30 ml of NH_4 OAc solution and shake for 30 minutes; centrifuge and transfer the supernatant into the same volumetric flask.
4. Repeat step 3 once more and transfer the supernatant again into the same volumetric flask. Keep the residue for direct determination of CEC as described.
5. Make up the volume of the extract in the volumetric flask to mark with the NH4 OAc solution.
6. Determine K, Na and Ca by flame photometer, Mg and Mn by atomic absorption spectrometer, and fe colorimetrically using 0 – phenanthroline method. Calcium and Mg can also be determined by versenate titration.

3.3.4.0 NITROGEN DETERMINATIONS

Total nitrogen in soil by Regular Macro-Kjeldahl method

3.3.4.1 **Apparatus:**

1. Macro-Kjeldahl digestion – distillation apparatus.

3.3.4.2 **Reagents:**

1. Mercury catalyst tablets: If the ready-made mercury catalyst tablets are not available, the catalyst mixture can be prepared as follows:

   Mix 190g of K_2SO_4 and 5g of HgO and grind the mixture in a mortar.

2. Mix boric acid-indicator solution – Dissolve 80g boric acid (H_3BO_3) in 3,800 ml of distilled or deionized water by heating on a hot-plate at a low heat. Cool the solution, then add 80 mil of the mixed indicator solution (prepared separately by dissolving 0.099g of bromocresol green and 0.066g of methyl red in 100ml of 96% ethanol). Add 0.1 N NaOH through a buret until the solution becomes reddish – purple tint (pH 5.0). Dillute the solution to 4 litres with distilled or deionized water. Mix the solution thoroughly before use.

3. Sodium hydroxide, NaOH, approximately 10 N. Weigh 2.1 kg of NaOH pellets in a heavy-walled 5-liter pyrex glass bottle or flask, add 2 liters of distilled water and swirl the flask until the alkali is dissolved. Cool the solution with a stopper in the neck of the flask to prevent absorption of atmospheric CO_2 and allow it to stand for several days to permit any Na_2CO_3 present to settle. Siphon the clear supernatant liquid into a large pyrex bottle which contains about 1 litre of CO_2 – free water and is marked to indicate a volume of 5liters, and make the solution to 5 litres by adding CO_2-free water.

   Swirl the bottle vigorously to mix the contents and fit the neck with some arrangement which permits the alkali to be stored and dispensed with protection from atmospheric CO_2.

4. H_2SO_4 Conc. AR

5. HCL (or H_2SO_4), 0.01 N, standard.

6. K_2SO_4, AR

3.3.4.3 PROCEDURE

1. Weigh 5 to 10g of soil sample containing about 10g of N (air-dried, ground to pass 0.5mm sieve) in a dry 500ml

macro-kjeldahl flask, add 20ml of distilled water. Swirl the flask for a few minutes, then allow it to stand for 30 minutes.

2. Add 1 tablet of mercury catalyst (or 1g of the $K_2SO_4^-$ -HgO) mixture catalyst) and 10g of K_2SO_4. Then add 30ml of conc. H_2SO_4 through an automatic pipet.
3. Heat the flask cautiously at low heat on the digestion stand. When the water has been removed and frothing has ceased, increase the heat until the digest clears. Then boil the mixture for 5 hours. Regulate the heating during this boiling so that the H_2SO_4 condenses about middle of the way up the neck of the flask.
4. Allow the flask to cool, and slowly add about 100ml of water to the flask.
5. Carefully transfer the digest into another clean macro-kjeldahl flask. Retain all sand particles in the original digestion flask because sand can cause severe bumping during kjeldahl distillation. Wash the sand residue with 50ml of distilled water 4 times and transfer the aliquot into the same flask.

6. Add 50ml H_3BO_3 – indicator solution into a 500 ml Erlenmeyer flask which is then placed under the condenser of the distillation apparatus. The end of the condenser is about 4 cm above the surface of the H_3BO_3 solution.
7. Attach the 750ml kjeldahl flask to the distillation apparatus. Pour about 150 ml of 10 N NaOH through the distillation flask by opening the funnel stopcock. Commence distillation immediately.
8. Keep condenser cool (below 30^{0}C) by allowing sufficient cold water to flow through, and regulate heat to minimize frothing and prevent suck-back.
9. Collect 150 mil distillate and then stop distillation.
10. Determine the NH_4-N in the distillate by titrating with 0.01 N standard HCL (or H_2SO_4) using a 25-ml burette graduated at 0.1-m interval. The colour change at the end-point is from green to pink.
11. Calculate the % N content in soil.

3.3.5.0 WATER ANALYSIS

3.3.5.1 Colorimetric determination of NO_3-N by phenol-disulphonic acid method.

3.3.5.2 Apparatus:

1. B & L spectronic 20
2. Evaporating dishes, 8-cm diameter
3. Water bath
4. Volumetric flasks, 100-ml capacity.

3.3.5.3 Reagents:

1. Ammonium hydroxide: appropriately 7 N (1 + 1),
2. a: phenoldisulphonic acid: Dissolve 25 g of phenol in 150 ml of conc. H_2SO_4 and 75 ml of fuming H_2SO_4 (13 to 15% SO_3), and heat at 100°C for 2 hours.

   b. Reagent bottle of phenoldisulphonic acid already prepared by manufacturers.

3. Potassium nitrate, KNO_3, 0.01N: Dissolve 1.011g of dry KNO_3 in water and dilute to exactly 1 litre.

3.3.5.4 PROCEDURE

1. Pipette a 10-ml aliquot of the extract into an 8-cm evaporating dish. Evaporate to dryness on a water bath and allow to cool.
2. Dissolve the residue in the evaporating dish in 2 ml of phenoldisulphonic acid reagent. Rotate the dish in order to wet all the residue with the reagent.

3. After 10 minutes, and 10 ml of water and transfer to a 100-ml volumetric flask.
4. Make content in volumetric flask alkaline by adding 40ml of NH_4OH (1 + 1). Dilute to volume and mix.
5. Measure absorbance of the yellow solution at 460 nm.

3.3.5.5 Standard Curve

Prepare standard curve by pipetting 0, 0.2, 04, 0.8, 1.2 and 1.6 ml portions of reagent 3(0.01N KNO_3) into evaporating dishes and treating as stated above in steps 2 to 5.

3.3.5.6 Colorimetric determination of NO_3-N in soil extract using the brucine method.

3.3.5.7 Apparatus:

B & L spectronic 20 or 70.

3.3.5.8 Reagents

1. Brucine, 2.5%. Dissolve 2.5g of brucine or brucine sulphate in 100ml of glacial acetic acid. Store in the dark. This reagent should be handled with care as it is very toxic.
2. H_2SO_4, conc. Sp. Gr. 1.84.
3. Standard nitrate – nitrogen solution; Dissolve 0.1805g of KNO_3 in 500 ml of water or extracting solution. Add 0.5

ml of chloroform as a preservative. Dilute 10ml to 100ml. This solution contains 5 ppm NO_3 – N.

3.3.5.9 PROCEDURE

1. Transfer a 10-ml aliquot of the soil extract into a 25-ml volumetric flask.
2. Add 2 ml of brucine reagent and then rapidly 10ml of con. $H2SO_4$.
3. Mix for about 30 seconds and allow the samples to stand for 5 minutes.
4. Let the flasks set in cold water for about 5 minutes or air cool for 15 minutes. Make up to mark.
5. Measure absorbance at 470 nm.

3.3.6.0 Standard Curve

Pipette, 0, 2, 4, 6, 8 and 10-ml aliquots of the standard solution into 25-ml flasks and treat as described for steps 2 to 5. The final concentrations of NO_3-N will correspond to 1, 0.4, 0.8, 1.2, 2.6 and 2.0 ppm in the standard solutions.

3.3.6.1 SULPHUR DETERMINATION

Turbidimetric determination of sulphate in plant digest, soil extracts and in water.

3.3.6.2 Apparatus

1. Bausch and Lomb spectronic – 70 Electrophotocolorimeter.
2. Volumetric flasks, 25-ml.

3.3.6.3 Reagents:

1. Galatin (Difco Bacto Galatin)
2. Barium Chloride ($BaCl_2.2H_2O$), AR
3. Gelatin – $BaCl_2$ reagent.

Dissolve 0.6 g of gelatin in 200 ml hot (60 – 70°C) distilled water and allow the solution to stand in a refrigerator (4°C) for 16 hours. After 16 hours, bring the semi-gelatinous fluid to room temperature, add 2g of reagents grade barium chloride and mix the content until $BaCl_2$ is dissolved. Store the solution in a refrigerator and allow the reagent to stand at room temperature for at least 2 hours before use.

4. Standard SO_4-S stock solution (100 ppm): Dissolve 0.5434 of reagent grade anhydrous potassium sulphate (K_2SO_2) in distilled water in a 1 litre volumetric flask and make up to volume to give a final concentration of 100 ppm SO_4-S, or 100 ug S per ml. Store in a reagent bottle.

5. Working S standard solution (25 ppm): Pipette 25 ml of the 100 ppm stock solution and dilute to 100 ml with distilled water. This standard solution contains 25 ug S per ml.

3.3.6.4 PROCEDURE

1. Pipette 10 ml of the sample aliquot into a 25-ml volumetric flask. Add distilled water to bring the volume to approximately 20 ml.
2. Add 1 ml of the gelatin – BaCl2 reagent. Make up to volume with distilled water. Mix the content thoroughly. Allow the content to stand for 30 minute.
3. Determine the % T and O. D at 420 nm within 30 minutes on a B & L spectronic – 70 electrocolorimeter. Shake the content in the flask before pouring into the photo-test tube.
4. Prepare a set of standard S solutions containing 0, 25, 50, 75, 1000, 125 ug SO_4-S per 25 ml from the working standard solution. The standard solution should, of course, contain 1ml of gelatin – BaCl2 reagent and 10ml of the blank digest or extracting solution.

NOTE: Difco Bacto gelatin can be purchased from Difco Laboratory, Inc., Detroit, Michigan, USA.

3.3.6.5 **EXTRACTION OF SOLUBLE SULPHATE** (Available S) in soil using morgans reagent.

3.3.6.6 Reagents

1. Sodium acetate (NaOAc)
2. Acetic acid (HOAc) (99.5%)

The morgan's reagent is prepared by dissolving 100g of NaOAc and 30ml of 99.5% HOAc in 500ml of water in one little volumetric flask. The solution is made to mark with distilled water.

3.3.6.7 Procedure

1. Weigh 20g of air-dry soil into 250-ml conical flask.
2. Add 100ml of morgan's extraction solution and shake for 30 minutes.
3. Filter through whatman's No. 42 filter paper (or centifuge until clear).
4. Measure SO_4 concentration turbidimetrically as described above.

3.5.7.0 **CALCIUM DETERMINATION**:

1. Place in a 250 – ml conical flask 50ml distilled water, 20ml of 20% KOH and 20ml of the extract.
2. Add 0.05 of calcium indicator powder.
3. Titrate against 0.02 N versenate until the green fluorescent colour just disappears, leaving a yellowish – pink colour as the end-point.

NOTE: Strong KOH is used to maintain a pH of 12 or above. If pH falls below 12 the indicator – calcium compound breaks down, and there will be no end-point to the titration.

Calculation: If V_1 is the volume of versenate used in the titration.

$$Ca^{2+} \text{ (in meq/100g soil)} = N \times V_1 \times \frac{100}{20} \times \frac{100}{S}$$

Where:

N = Normality of versenate
V_1 = Volume of versenate
S = Weight of soil used.

3.3.7.1 **CALCIUM PLUS MAGNESIUM**

1. Place 50ml of distilled water in a 250ml conical flask, and add 25ml of conc. Ammonia solution.
2. Add 20ml of extract i.e. water or soil = extract.
3. Add 5drops of the Eriochrome Black T indicator solution and 1ml of 2% NaCN.

3.3.6.8 DETERMINATION OF CALCIUM AND MAGNESIUM BY VERSENATE TITRATION METHOD:

3.3.6.9. Reagents:

1. Standard Ca solution on: 0.5005g of pure dried $CaCo_3$ is dissolved in 10ml of 0.2 N HCL. The solution is boiled to expel CO_2 before being diluted to 1 litre. This solution is 0.01 N with respect to calcium.
2. Conc. NH_4OH solution.
3. Eriochrome Black T indicator: Weigh 0.5g of Eriochrome Black T indicator plus 4.5g of hydroxylomine hydrochloride. Dissolve a mixture of the two reagents in 100ml of methanol.
4. NaCN (2% solution): Dissolve 2 g of NACN in distilled water and make up to 100ml in a volumetric flask.
5. Calcium (Murexide): 1g of calcium is ground up with 100g of K_2SO_4.
6. KOH (20% Solution): Dissolve 200g of KOH in distilled water and make up to 1 litre.
7. Versenate or E.D.T.A Solution (N/50): Dissolve 3.72g of E.D.T.A disodium salt in water and make up solution to 1 litre.

4. Titrate the solution with 0.02 N versenate to a bright blue and point. This titration is a measure of the total Ca plus mg in the sample aliquot used.

Calculation: if V_2 is the volume of versenate used in the above titration, then $Ca^{2+} + Mg^{2+}$ (in meq/100g soil) = $\underline{N} \times V_2 \times 5 \times \frac{100}{S}$

The amount of mg^{2+} (in meq/100g soil) is obtained by subtracting the value of calcium from the value obtained for $(ca^{2+} + mg^{2+})$

3.3.7.2 CHLORIDE DETERMINATION:

3.3.7.2 Apparatus:

1. Beaker (150-ml capacity
2. Pipette (50-ml capacity)
3. Burette.

3.3.7.4 Reagents:

A. Potassium chromate indicator: Dissolve 5g of K_2CrO_4 in water and saturated solution of $AgNO_3$ until a slight permanent red precipitate is produced. Filter and dilute to 100-ml.

B. Standard silver nitrate, $AgNO_3$, solution; 0.05N. Dissolve 8.4944 of Ag NO_3 in water and dilute to 1 litre. Check by titrating against pure NaCl or standard KCl.

3.3.7.5 Procedure

To the solution from the carbonate and bicarbonate determination, add 1 ml of reagent A and titrate with B. Correct for the quantity of AgNO3 solution necessary to give, in 50 ml Cl-free water with 1ml K_2CrO_4 indicator, the shade obtained at the end of the titration of the sample.

If the size of aliquot that is suitable for the carbonate-bicarbonate titration is too large for the chloride determination, a smaller aliquot should be taken and neutralized to methyl orange. The aliquot should not contain more than 2 meq of chloride.

Calculation:

Meq/1 of Cl = 1000 x N of $AgNO_3$ (ml $AgNO_3$-blank)/
Kl in aliquot.

3.3.7.6 Water Analysis by Atomic and Flame Emission

3.3.7.7. **Scope**: This method provides for the determination of several elements in streams, ponds, lakes and other forms of water that are used for agricultural and domestic purposes.

3.3.7.8 **Standards**: These are prepared from stock solutions by dilution with HNO_3. They should contain the elements of interest in the concentration range expected in the samples. For the determination of K, standards and samples should contain 1000 ppm Na to prevent ionization interference. They should also contain 1% La if air acetylene flame is used for determining Ca and Mg.

3.3.7.9 **Sample Preparation**:

Water samples should be collected and stored in acid – cleaned plastic bottles. Concentration of the elements may be necessary, depending on the particular element concentration in the original sample; generally, the concentration is necessary.

3.3.8.0 **Procedures:**

1. Transfer 500ml of the water sample into the evaporating dish.
2. Add 15ml of conc. HNO_3.
3. Evaporate on a steam bath to approximately 25ml
4. Transfer to a 50-ml acid – washed volumetric flask.
5. Bring to volume with deionized water
6. Analyse for K, Ca, Na, Mg, Cu, Fe, K. Mn, Zn and N. Using either atomic absorption or flame photometry. For the analysis of Ca and Mg with air-acetylene transfer 10ml of prepared sample to an acid-washed 50-ml volumetric flask. Add 10-ml of 5% La solution and bring up to volume with deionized.

CHAPTER FOUR

4.1 RESULTS AND DISCUSSION

4.1.1 The results of the chemical analysis of the soil and water.

After the completion of the various soil analyses and the water quality analyses of salts present in the Okada Irrigation Scheme, the following results were obtained for the salt composition of the soil and water.

ANALYSIS RESULT SHEET – SOILS

ab um- er	Sample Descrip- tion	Bulk density	Total Nitro- gen	Exchange Cations Meq/100gm soil				CEC	ESP	Sand	Silt	Clay	Tex- tured Class
	Depth (cm)	G/cm³	%	Na^+	K^+	Ca^{+2}	Mg^{+2}	Mg/ 100g M soil		%	%	%	
	0-20	1.35	0.251	0.76	0.25	18.50	0.25	19.71	3.86	74.8	15.16	10.76	S.L
	20-40	1.41	0.200	0.52	0.32	5.00	0.30	6.14					
	40-60	1.63	0.157	0.18	0.34	12.30	1.65	14.67	8.47				
									1.23				
	0-20	1.27	0.152	0.55	0.56	7.15	3.27	11.53	4.77	69.44	16.08	14.48	S.L
	20-40	1.55	0.99	0.62	0.18	13.20	6.11	20.11	3.08				
	40-60	1.59	0.068	0.86	0.12	5.11	0.57	6.66	12.91				
A	0-20	1.36	0.183	0.37	1.26	9.15	5.81	16.59	2.23	74.16	10.08	15.76	S.L
	20-40	1.41	0.127	0.63	0.83	6.28	3.91	11.65	4.41				
	40-60	1.77	0.057	0.70	0.87	5.87	1.67	9.09	7.70				
B	0-20	1.46	0.142	0.19	0.41	6.56	0.92	8.08	2.35	67.44	11.80	20.76	S.L
	20-40	1.80	0.058	0.74	0.58	3.44	0.66	5.42	13.65				
	40-60	1.80	0.026	0.36	0.43	6.50	1.20	8.49	4.24				

4.1.3 Water Sample Results

cation of mple	PH	TDS	EC	ESP	SO_4^-	Cl^-	Ca^{+2}	Mg^{+2}	Na^+	K^+	CEC
S1	6.5	73	75	15.28	0.32	5.0	20	1.37	3.88	0.14	25.39
S2	6.8	150	61	11.87	4.69	11.25	25	16.40	5.61	0.27	14.28
IS1	5.5	105	102	2.10	41.25	10.00	30	13.50	1.30	17.91	62.71
IS2	6.3	30	65	0.50	6.91	15.00	35	10.44	0.27	11.80	57.51

NOTE: Electrical Conductivity (EC) at 25°C micromhos/cm.
Cations and Anions are in mg/L

4.1.4 **CALCULATIONS**

$$ESP = \frac{100\ Na+}{Ca^{+2} + Mg^{+2} + Na^{+} + K^{+}}$$

pH = Unitless

$$:.\ Esp\ at\ UPS1 \quad \frac{100\ Na+}{Ca^{+2} + Mg^{+2} + Na^{+} + K^{+}}$$

$$\frac{100 \times 3.88}{20 + 11.37 + 0.14 + 3.88} \quad \frac{388}{35.39} \quad = 10.96$$

:. Esp at UPS1 = 11.0%

USP2 = 11.87%
DNS1 = 2.10%
DNS2 = 0.50%

2. The sodium adsorption ratio (SAR) $\frac{Na^{+}}{\frac{\sqrt{Cca^{++} + Mg^{++}}}{2}}$

SAR at the UPS.1 $\frac{3.88}{\frac{\sqrt{20 + 11.37}}{2}}$

$$\frac{3.88}{\sqrt{20 + 11.37}} = \frac{3.88}{3.96} = 0.98$$

= 0.9796
= 0.98

:. SAR for UPS2 = 1.23
" " DNS1 = 0.28
" " DNS2 = 0.06

Where,

SAR = Sodium Adsorption Ration
UPS1 = Upstream Section 1
UPS2 = Upstream Section 2
DNS1 = Downstream Section 1
DNS2 = Downstream Section 2
ESP = Exchangeable Sodium Percent
TDS = Total Dissolved Salt
S.L = Sandy Loam
EC = Electrical Conductivity.

4.1.5 Classification of Soil Based on Electrical Conductivity:

Table 4.2

Soil	Electrical Conductivity of Saturation Extract mm/hos/cm at 25°C	Exchangeable Sodium
Saline	Greater than 4	Less than 15
Alkaline	Less than 4	Greater than 15
Saline-Alkaline	Greater than 4	Greater than 15

4.2.0 Soil Analysis results of SO_4^-, Cl^-, PO_4 Meq/Litre:

Table 4.3

Location of Sample	SO_4^-	Cl^-	PO_4^-	NO_3^-
1A	3.11	6.81	7.05	0.100
1B	1.06	3.53	7.11	0.025
2AA	4.32	0.45	7.60	0.050
2BB	2.51	1.86	7.05	0.052

4.2.1 Water Sample Analysis Meq/Litre

Table 4.4

Location of Sample	NO_3^-	PO_4^-
UPS 1	16.22	4.84
UPS 2	12.58	7.10
DNS 1	10.35	5.51
DNS 2	13.68	2.25

4.2.2 Salinity Assessment of Water Based on Electrical Conductivity Value

Table 4.5

Electrical Conductivity mhos/cm At 25oC (degree centigrade)	Salinity Assessment
Less than 250	**Low Salinity**
250 – 750	**Medium Salinity**
750 – 2250	**High Salinity**
Greater than 2250	**Very High Salinity**

Table of Rating of Exchangeable Cations

Table 4.6

Rating		Range		CmOl/kg Soil
	Exch. Ca	Exch. Mg	Exch. K.	Exch. Na
Very high	>20	>8	1.0 – 2	>2
High	10 – 20	3 – 8	0.6 – 1.2	0.7 – 2
Moderate	5 – 10	1 – 3	0.3 – 06	0.3 – 0.7
Low	2 – 5	0.3 – 1	0.2 – 0.3	0.1 – 0.3
Very low	<2	<0.3	<0.2	<0.1

Table of Rating of Total Nitrogen (N)
Table 4.7

Total N	
Very Low	<0.050% N
Low	0.050% N
Moderate Low	0.101 – 0.150% N
Medium	0.151 – 0.150% N
Moderate high	0.201 – 0.250% N
High	0.251 – 0.300% N
Very High	>0.300% N

4.3.0 Discussions of results of Salts build-up in the Irrigation Scheme

The results of the chemical analyses of soil and that of the water samples indicated that there are different salts present in the irrigation scheme that are harmful to soil and plants grown.

For the soil analysis results, there is a large deposit of sodium at the top layer of the soil which is a harmful salt. The exchangeable sodium cations at the depths between 0.60cm has an average rating of 0.62 above, which indicates high exchangeable cation of sodium in the soil.

Potassium was discovered to be above moderate which indicated the use of sulphate fertilizers, which also has its own negative and positive effect on some crops on the field.

Calcium was also discovered to be moderate, in the farmlands.

Magnesium on the other hand was found out to be low in the soil.

The results of the salts in table 4.3 shows that nitrate is very low and phosphate is very high. There is a low sulphates and chlorides too in the scheme.

The results of the water sample analysis in tables 4.1 and 4.3 show that the salts at the upstream to be very low before the water was pumped into the scheme for use, because high in the scheme after mixing with the salt in the soil and reduced drastically after the water was diverted back to the main water channel.

The PO_4^- and NO_3^- composition are slightly high so there is a need to either amend the composition or recommend crops that could be tolerant to such compositions.

The pH of the soil and water are moderately favourable to plant growth. The application of potassium had been noticed to have positive impact on the soil and water at different sources of sample collections.

Phosphorus and irrigation interactions were significant on the soil analysis as phosphate in soils. These were expected as water application ensures the availability of nutrients for absorption and translocation in crops system, resulting in good vegetative growth as well as fruit formation in the reproductive phase of crops. Leaching of the salts should also be encouraged.

To solve the problem posed by using salt water or poor quality water for irrigation where there is no substitute, grow salt tolerant crops. For example, it is possible to grow a salt tolerant crops like cotton or spinach with relatively medium salt content, where the water is applied in excess of the crop need under proper management practices.

CHAPTER FIVE

5.0 OBSERVATION, CONCLUSION AND RECOMMENDATIONS:

5.1 OBSERVATION:

It was observed during the cause of the experiment that farm management practices being adopted by the farmers in the scheme were too old and the subdivisions of the scheme into smaller parts makes it difficult to actually get good use of any system being used in commercial basis.

The soil profile of the river channel was done half way into the scheme by Julius Berger Nigeria Plc, which has rendered the scheme to be proned seriously to erosion menace and flooding of the banks. The physical characteristics are properties which are often apparent to the casual observer, the colour of the water was greenish, has bad odour. Some of the plants were showing signs of some micro-nutrients deficiencies like boron deficiency being evidenced on the leaf tips of Okra on the field; yellow colouring of vegetables like spinach were observed to be pronounced.

5.2 **CONCLUSION:**

The impact of salts build-up in the Okada Irrigation Scheme is mostly being felt due to excessive salts in the soil and water, and moreso, the ever changing-hydrological cycles in the area

The poor use of water quality and the accumulation of salts in the soil due to evapotranspiration, the wrong application of fertilizer, the timing of the irrigation period and drainage system, all contributed to the salts build-up in the area.

Some crops that were planted during the irrigation season suffered severe stress due to lack of water to be applied into the fields; this was due to the fact that the river normally runs dry between the months of April and May, thereby subjecting some of the crops on the field to wilting, produce less or do not reach reproductive stage before they die. The pattern of crops growth and the hydrological information of the area should be strictly adhered to, to reduce the rate of lack of water being experienced in the river at some particular time of the year i.e. between the months of April and May before the advent of rainfall commences.

5.3 RECOMMENDATIONS:

The use of good farm-management systems, the provisions of farm inputs in form of credit loan schemes by banks. The use of improved seedlings, to increase their crop productive levels.

Proper irrigation management can slow down or stop salinization. Perhaps the most effective remediation is an increase in irrigation efficiency. Any water which has been lost to evaporation has increase salinity, but not contributed to plant growth. Therefore, techniques which minimize evaporation also minimize salinization.

Moreso, agricultural inputs to farmers should be subsidized in order to form self-sustaining economies, however subsidy should be the exception and not the rule. The subsidy should be in the area of fertilizer inputs, the machines (pumping engine) should be bought by government and lent out; tractors, ploughs, harrows and ridgers.

The government should come to the aid of the farmers in the area of post harvest storage facility, provisions and techniques to save the enormous waste of the farm produce during the harvesting periods. Provision of good transport system, roads to and from farm, Agricultural Extension officers, soil and water scientists should visit these farmers and to impart in them the latest agricultural techniques and management systems. Low quality water should be avoided as possible.

Reclamation measures and procedures should be carried out to bring the saline and alkali soils into reproductive condition to maximize yield of crops on the field (Okada Irrigation Scheme).

Finally, to arrest the salts build-up in the scheme, the planting of salts tolerant crops should be encouraged and practiced by the farmers such as:- onion, cabbage, lettuce, carrot, tomato, maize, pumpkin, sweet potato, cotton, sugar-cane and wheat.

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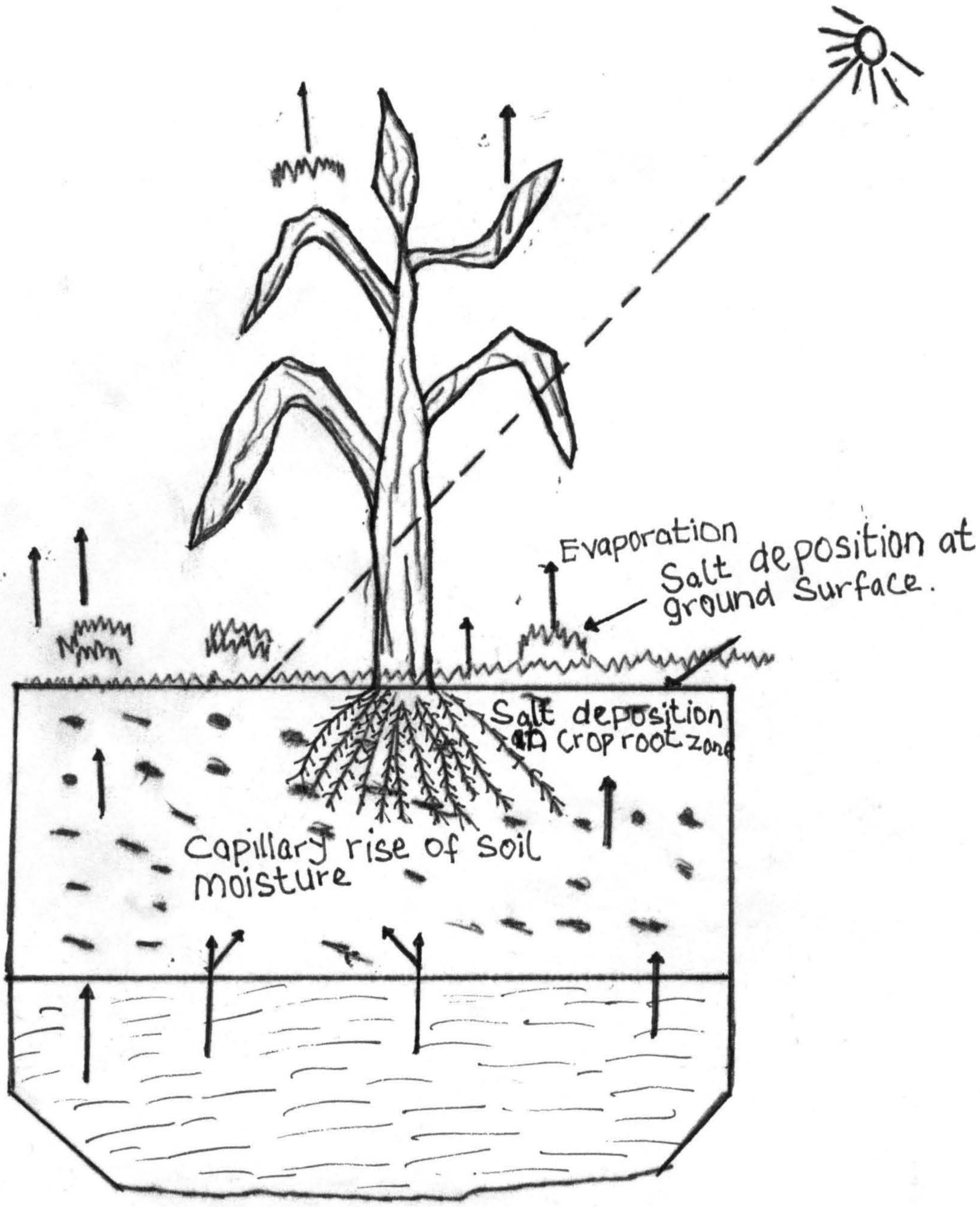


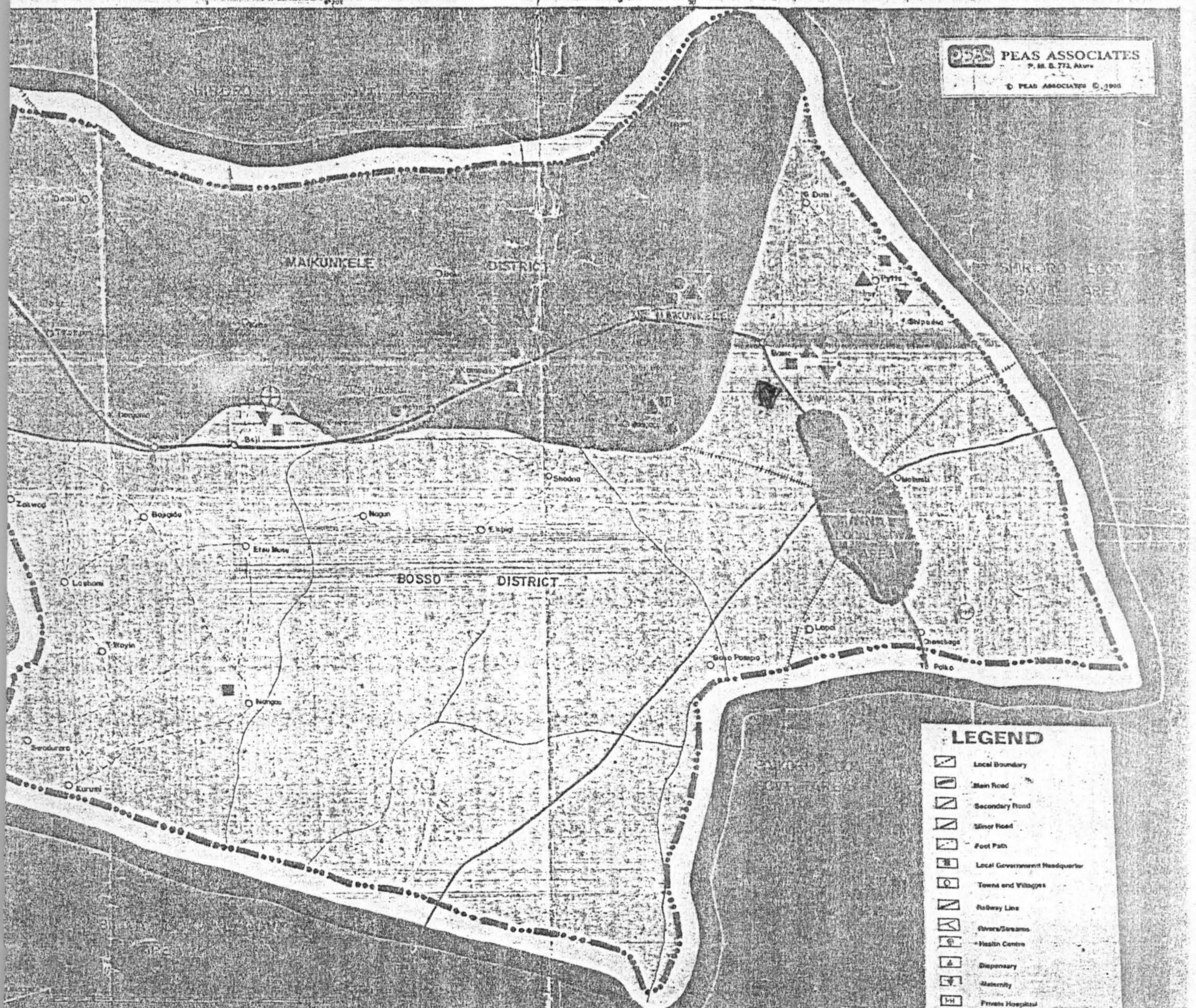
FiG. 1.0 Schematic illustration of Salt build-UP in soil due to high Water table.

X-1

BOSSO LOCAL GOVERNMENT

NIGER STATE, NIGERIA.

BOSSO DISTRICT



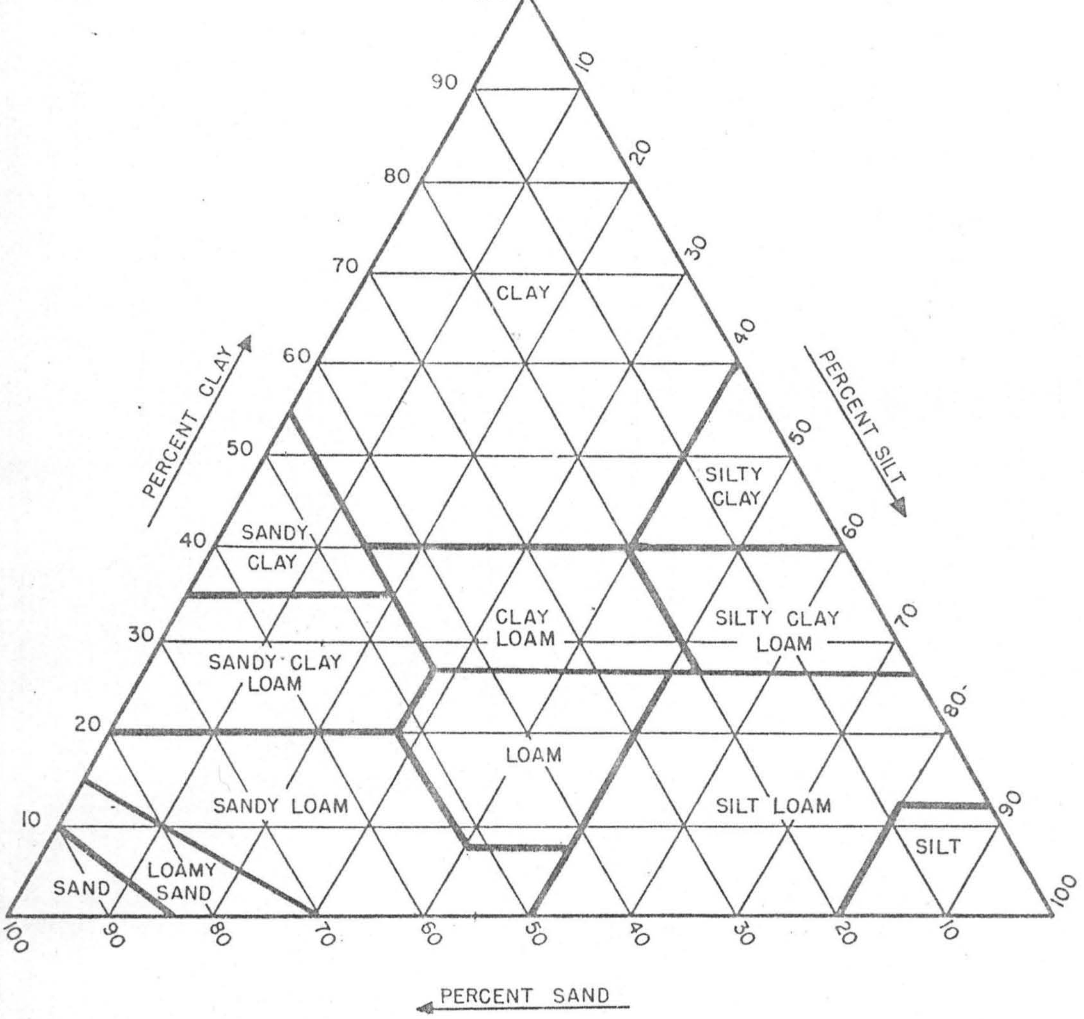


Figure 3.0.--Proportions of sand, silt, and clay in the basic soil-textural classes. (From U.S. Dept. Agr. Handb. 18. Soil Survey Manual. 503 pp., illus. 1951.)

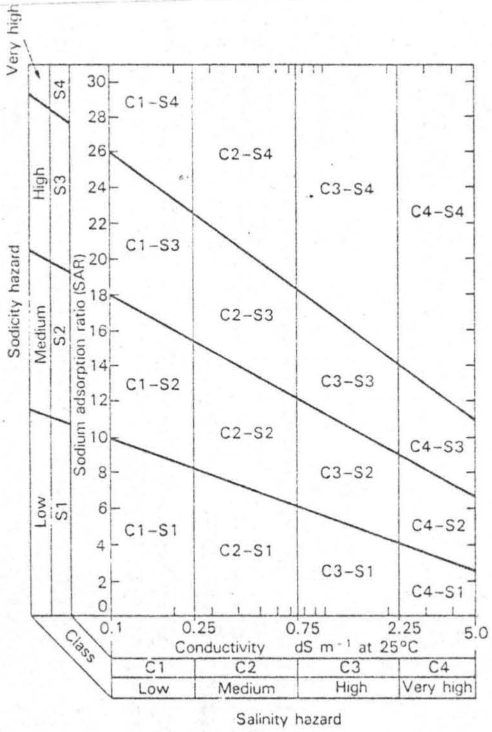
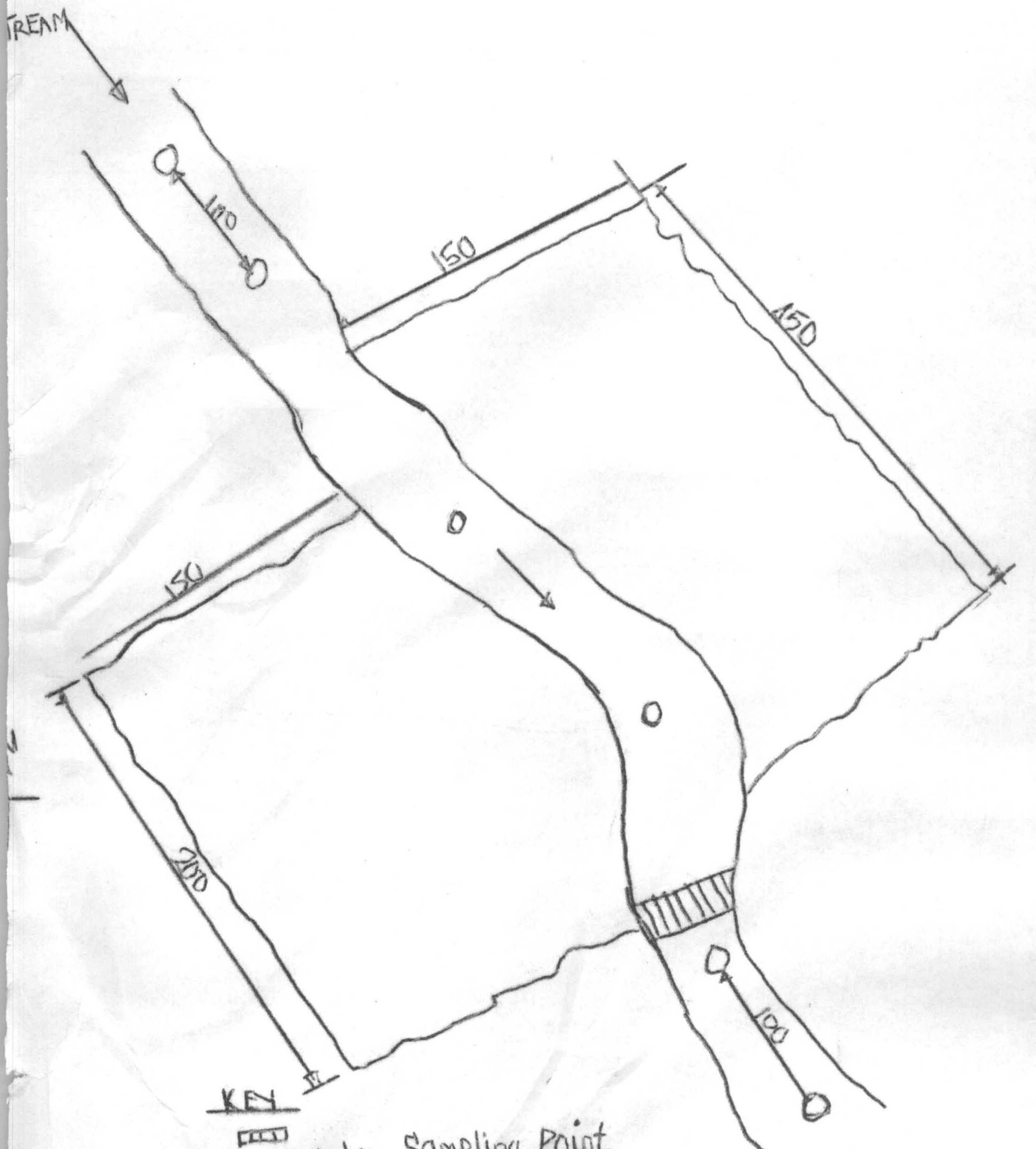
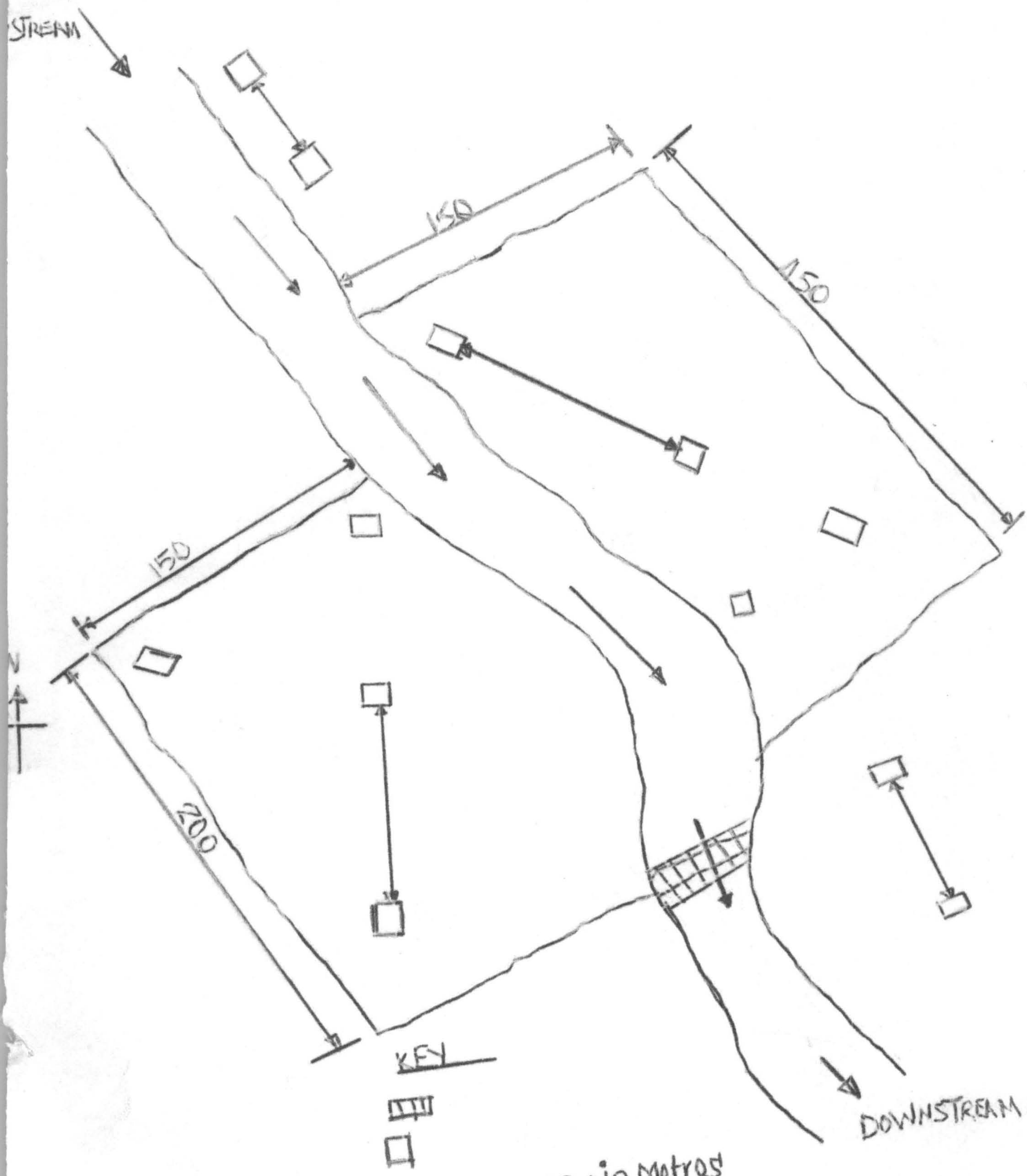


Diagram for the classification of irrigation water.

SAMPLING POINTS - WATER APPENDIX 5



SAMPLING POINTS—SOIL APPENDIX 6



* All dimensions are in Metres