EVALUATION OF GROUNDWATER QUALITY FOR IRRIGATION IN GBAKO DRAINAGE BASIN, NIGER STATE.

BY

M. MOHAMMED
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CERTIFICATION.

The dissertation entitled " Evaluation of Groundwater Quality for Irrigation in Gbako Drainage Basin" by M. Mohammed meets the regulations governing the award of post-graduate diploma (PGD) of the Federal University of technology, Minna and is approved for its contribution to knowledge and literary presentation.

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Engr. Mrs. D.Z. Osunde Date

Supervisor

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Dr. M.G. Yisa Date

Head, Dept. of Agric. Engineering

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Prof. J.O. Adeniyi Date

Dean, Post-Graduate School

DEDICATION

To the memory of my late father, Alhaji Mohammed Ndagimba.

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ABSTRACT

The quality of the groundwater in Gbako Drainage basin of Niger State was evaluated r its suitability as source of water in irrigation. The soils were sampled to depths of 0-15cm, 5-30cm and 30-60cm. Laboratory analysis of these soils gave textures ranging from loamy and top soils of Edozhigi, Bida and Majingari to the sandy loams of Agaie and Kudogi with lay content increasing down the soil profile. Groundwater was sampled by pumping from ach tube well for five minutes. Routine cations were determined using Shimadzu pectrophotometer while the anions were determined by titration. The water is of low to medium salinity (class $C_1 - S_1$) with values ranging between 168μmhoscm^{-1} and 410.52 μmhos cm^{-1}. The sodium hazard measured as sodium adsorption ratio (SAR) gives low risk of sodium alkalinization with values ranging from 0.06 to 0.09. The groundwater reaction was acidic but sufficiently moderate for adequate nutrient availability to crops. The various chemical elements of the groundwater are well below the limits required by the Food and Agricultural Organization (FAO) and the World Health Organization (WHO) for irrigation. These results therefore underscore the importance of evaluating water for irrigation if the present level of food production is to be improved upon.

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INTRODUCTION

With the food requirement rising and the tasks of producing food become more complicated, there is a great need to conserve our limited natural resources and to manage them for higher agricultural production. Water is one of the major inputs in agriculture and the whole production system is highly dependent on its reliable supply. Nothing grows without it. Without water, life is impossible for the simple reason that the other elements of the earth combine with water to constitute living plant or an animal by overheating it and nothing remains but dry matter and ashes which can never be restored to life.

From time immemorial, man has learnt to modify his behavior depending on the presence or absence of water and has been forced to accept schedules and timetables determined by climate and geographical factors that are beyond his control (Dupriez and Leener, 1992). At the same time, however, man has always tried to tame the water within his reach. Throughout the world, water management is a basic human activity through the control of run off, flooding and spate flow, the storing of small or large quantities of water, water quality, crop irrigation and swamp drainage. Managing water is part of natural economies because of its several purposes- the improvement of agriculture and livestock, the reduction of ecological and human catastrophes (droughts and flooding, for instance), and all the activities of enterprises charged with water development projects.

The major source of water in arid and semi-arid regions is precipitation, mostly rainfall. Maheswari and Correia (1984) reported that rainfall in these areas is low, varies from 50 to 500mm in arid regions and is quite erratic. The failure of rainfall at the critical period of plant growth or long dry spells during cropping season, generally, results in heavy reduction in yield per unit area. To stabilize agricultural production in these areas, irrigation needs to be stepped up. 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 amount and kind of salts present will determine the suitability of water for irrigation. With poor water quality, various soil and cropping problems can be expected to develop.

According to Michael (1978), 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 are present in minor quantities. These elements usually do not affect the quality of irrigation water as far as the total salt concentration is concerned. Among the soluble constituents, Calcium, Magnesium, Sodium, Chloride, Sulphate, Bicarbonate and Boron are of prime importance in determining the quality of irrigation water and its suitability for irrigation purposes. However, other factors such 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.

In any evaluation of groundwater resources, its physical, chemical and biological characteristics are of major importance in determining whether or not water is suitable for domestic, industrial or agricultural use. Furthermore, details appertaining to groundwater quality may throw light on such factors as the interconnection between surface water and aquifers, groundwater movement and storage. When water infiltrates into the ground its quality is modified by a number of processes. For example, the amount of precipitation which moves into and evaporation loss from the ground influence the character of the soil water, as does the reaction of the later with the soil particles. Of particular importance is the role played by water as an agent of chemical weathering which leads to the dissolution of minerals.

In recent years it has been recognized that the quality of groundwater is of nearly equal importance to quantity. As greater development and use of groundwater continues, combined with the reuse of water, quality suffers unless consideration is given to protecting it. Invariably, encroachment by man increases opportunities for pollution. The quality required of groundwater supply depends upon its purpose; thus, the needs for drinking water, industrial water and irrigation water vary widely.

1.1 RESEARCH OBJECTIVE

i. Investigate the quality of groundwater within the drainage basin.

ii. Highlight the variation in quality.

iii. Determination of its agricultural significance.

1.2 PROBLEM STATEMENT.

The variation and frequent unreliability of rainfall and unpredictable period of drought inform the need for this study in the geographical location. In this area, the number of cultivated or uncultivated crops which survive the dry seasons are prolonged and the raining seasons unreliable. For watering during the dry season, in which irrigation enables dry land cropping or off-season cultivation, one must obviously be sure of having enough good quality water to last the dry season.

1.3 SCOPE OF STUDY

The area covered in this research includes; Gbako (Edozhigi), Bida, Agaie and Lavun (Majingari and Kudogi) Local Government areas (Appendix 1). The parameters to be determined are: cations (Calcium, Magnesium, Sodium and Potassium), anions (Chloride, Nitrate and Bicarbonate), pH, electrical conductivity and total dissolved solid (TDS).

1.4 JUSTIFICATION OF STUDY

The major requirement for a successful irrigation scheme is the availability of sufficient quantity and good quality water for irrigation purpose. It is obvious that the success of most irrigation schemes are halted by the unavailability of required volume and good quality water at the right time. This can be attributed to hydrologic, geologic and climatic variation between regions. This research is adequately justified by the fact that it assesses the suitability of underground water for irrigation.

2.0 LITERATURE REVIEW

In many parts of the world, irrigation systems are performing well below their potential. There is unanimous agreement among the irrigation community on the need to improve the operation of irrigation systems in order to increase agricultural productivity and meet an ever-increasing demand for good quality water. Anon (1993) showed that good planning and design have crucial implications for the success of an irrigation system. Selecting appropriate technologies to match cropping patterns, physical conditions and social economic conditions involves many complex and often conflicting considerations. The most important requirements are those of reliability of good quality water delivery to the users, flexibility of operation of the system and efficient use of water.

Studies by most water engineers and geologists have shown that groundwater from aquifers within the basement is sufficiently portable for most purposes, irrigation inclusive. Agricultural crops vary genetically and thus require different soil water regimes for optimum production. Egharevba and Mudiare (1999) reported that groundwater use; as a percentage of total water use by a crop can be affected by water table depth, soil type, climate and quality of the groundwater.

The suitability of groundwater for irrigation depends on the effects that the salt concentration contained there in has on plants and soils (Hamill and Bell, 1986). Salts may harm plant growth in that they reduce the uptake of water. The effects that salts have on some soils, notably the changes brought about in soil fabric that, in turn, affect permeability and aeration, also influence plant growth. In order words, cations can cause deflocculatiion of clay minerals in soil, which damage its crumb structure and reduce its infiltration capacity. In addition to the potential dangers due to high salinity, a sodium hazard sometimes exists in that sodium in irrigation water can bring about a reduction in soil permeability and cause the soil to harden.

Michael (1978) showed that several factors influence ground water quality for irrigation. The generally accepted criteria for judging the quality are: total salt concentration, as measured by electrical conductivity, relative proportion of cations as expressed by Sodium adsorption ratio (SAR) and bicarbonate and boron contents. Some other factors such like the depth of water of table, presence of hardpan of lime or clay. Calcium carbonate content in the soil and potassium and nitrate ions in irrigation water also indirectly effect the suitability of irrigation water. The soil type, major crops of the area, climate and drainage characteristics profoundly influence the suitability of particular water for irrigation. Highly saline water may be suitable in a well-drained, light textured, fertile soil while much less saline water may be more harmful for the same crop grown on a heavy textured soil with impeded drainage. It is the actual salt concentration near root zone, which determines the suitability of irrigation water rather than the chemical properties of irrigation water alone.

Research by Cormick and Algozin (1989) indicates that potential for fertilizers and pesticides to accumulate in groundwater depends on a combination of environmental and human factors. Local site conditions, such as climate, soil properties; depth to groundwater and the physical characteristics of the aquifer are important factor in determining the vulnerability to contamination.

Plants in saline soils are adversely affected by high concentration of salts in the soil solution and by poor physical condition of the soil. Both soil conditions are affected by irrigation water. Irrigation water having a high sodium percentage will, after a time, give rise to a soil having a large proportion of replaceable sodium in the colloid, often designated as "black alkali" soil. Even in sandy soil with good drainage, waters of 85 percent sodium of higher are likely to make soils impermeable after prolonged use (Hansen et al, 1979).

The quality of water depends on the amount of suspended sediment and the chemical and biological constituent in the water. The effect of sediment in irrigation water is influenced by the nature of the soil of the irrigated area. Schwab et al (1971) showed that if fine sediment is deposited on sandy soil, the textural composition and fertility might be improved. However, if the sediment has been derived from eroded areas, it may reduce fertility or decrease soil permeability. Sedimentation in canals or ditches increases maintenance costs. Normally, groundwater or water from reservoirs does not contain enough sediment to cause trouble in irrigation water, but for domestic supplies sediment is a problem.

The World Heath Organization (WHO) has set standards for water for various purposes. The standard set by WHO (1958) as presented by Raji (1990), in respect of irrigation seems to be inadequate. This is because the processes governing the movement and uptake of irrigation on the field are complex. Factors such as plant type, climate, soil and even the kind of management could render otherwise "safe" water by WHO standard "unsafe". It has therefore become necessary to use a combination of these factors in the evaluation of water for irrigation. A number of different irrigation water quality appraisal systems have been developed. Until recently, the system developed by the United State Soil Salinity Laboratory (1954) was widely used. The system proposed by FAO (1976) and presented by Smedema and Rycroft (1988) incorporates more recent research findings and experiences. In their studies, Dupriez and Leener (1992) reported that water salinity is often detected by testing or may observed when a water sample is evaporated in a container, but this is only a general indication. Laboratory analysis is needed for accurate information. Each type of salt is identified by a specific chemical analysis and much analysis may be needed to identify all the salts.

CHAPTER THREE

3.0 MATERIALS AND METHOD

The soil and water samples were analyzed at the Soil and Water and Chemistry Laboratories, Federal Polytechnic, Bida and Soil Science Laboratory, Federal University of Technology, Minna.

3.1 THE STUDY AREA.

The study area located between latitude 9° 00` and 9° 15` North and Longitude 6° 00` and 6° 20` West, comprises Gbako, Bida, Agaie and Lavun Local Government Areas of Niger State (Appendix 1). The area found within the basement complex and Nupe Sandstone is low lying with altitude between 142 and 150 metres above sea level.

The drainage pattern here, in general is dendritic and apart from the main surface watercourse, River Gbako, which is perennial, other seasonal and perennial rivers and streams are equally found in this area. The vegetation corresponds to Guinea Savanna and rainfall distribution is monomodal, varying between 1000mm and 1500mm and spread between 6 and 8 months (Suleiman, 1998).

Peasant farming dominated this area. Scattered holdings with size ranging from 0.5 hectares to 1.5 hectares are common in this area. The farming is mainly for subsistence, in which case most of the farm produce is consumed locally. Rice, which is the only economical crop, is grown on large scale in both wet and dry seasons. Other crops are sugar cane, vegetables (amaranths, tomatoes, pepper and okra).

3.2 SOIL SAMPLING

Samples of soil were collected from the groundwater sampling sites, spread all over the study area using a soil sampling auger to depths of 0 – 15cm for top soil and 15 – 60cm in steps of 15 – 30cm and 30 – 60cm for subsoil analysis. Individual cores were taken at each depth, mixed thoroughly and all foreign matter (leaves, roots, stones, etc) removed. Riffling was done on samples obtained from each layer using a riffle box so as to obtain a representative sample for the test. A total of 15 samples collected from the area were oven dried at 110°C for 24 hours to remove organic matter content before textural analysis was performed.

3.2.1 PARTICLE SIZE ANALYSIS

Particle size analysis was performed on each of the 15 samples obtained. A method described by Foth (1970) and presented by LaMotte Chemical Products Company (1988) was used.

Reagents and Equipment

Soil flocculating reagent, texture dispersing reagent, soil texture stand, soil separation tubes (50ml plastics) and pipette (18mm screw cap).

Test Procedure

1. Three soil separation tubes were marked for identification as A, B and C.
2. Soil sample was sieved using 2mm sieve and added to soil separation tube A until it is even with line 15 and the button gently tapped on a firm surface.
3. 1ml of texture dispersing reagent was added to the soil sample in tube A and water added to line 45. Tube A was capped and gently shaken for two minutes to ensure that soil sample thoroughly mixed in water.
4. The cap was removed and tube A placed in the rack and allowed to stand undisturbed for 30 seconds. All solution was later poured in to tube B and allowed to stand undisturbed for 30 minutes. Thereafter, the solution was poured in to tube C. Tubes A and B were then returned to the rack.
5. 1ml of soil flocculation reagent was added to soil separation in tube C, capped, shaken for one minute and allowed to stand for 24 hours until all clay in suspension settles. Percentage sand, silt and clay were computed using equation 1, 2 and 3.

$$\text{Percent Sand} = \frac{\text{Reading A}}{\text{Total volume}} \times 100 \text{ ------------------ } (1)$$

$$\text{Percent Silt} = \frac{\text{Reading B}}{\text{Total volume}} \times 100 \text{ ------------------ } (2)$$

$$\text{Percent Clay} = \frac{\text{Calculated volume}}{\text{Total volume}} \times 100 \text{ ------------------ } (3)$$

3.3 WATER SAMPLING

The groundwater samples were collected from tube wells in sampling sites (Appendix 1). In sampling, the water was collected in half gallon plastic bottles after rinsing the bottles with the water being sampled. Sampling was done by pumping from each tube well for five minutes to empty the casing pipe, clean the delivery pipe and to obtain representative samples. The bottles were securely corked, stored in a cool place and transferred promptly to the laboratory for analysis.

3.3.1 DETERMINTION OF pH

Reagents and Equipment.

Buffer solution, sample and pH meter [Kent Eil 7045 (46)] electrode.

Test Procedure

1. The electrode was dipped in to the solution of pH 7.
2. The temperature control was set to the temperature of the buffer.
3. The range selector switch was set to 0 – 14 pH position and the control knob was adjusted to read the pH value of buffer solution.
4. The range selector was switched to return the stand by position.
5. The electrode was removed from the buffer solution, washed with distilled water and immersed in to the solution to be tested.
6. The temperature control knob was set to the temperature of the test solution.

7. The range selection switch was again set to 0 – 14 pH position. Then the meter indicates the pH of the solution.

3.3.2 DETERMINATION OF ELECTRICAL CONDUCTIVITY (EC) AND TOTAL DISSOLVED SOLID (TDS).

Reagents and Equipment.

Sample, conductometer (E587) and electrode.

Test Procedure

1. The conductometer was switched on and allowed to warm-up for ten minutes.
2. The meter was standardized and the cell constant adjusted to 0.083.
3. The electrode was dipped into the sample and the reading recorded.

The total dissolved solid (TDS) was then determined using equation (4)

$$TDS = EC \times 2/3 \quad \text{---------------------} \quad (4)$$

3.3.3 DETERMINATION OF CALCIUM, MAGNESIUM, SODIUM AND POTASSIUM

CALCIUM(Ca)

Reagents and Equipment.

Calcium standards, 0 ppm, 50 ppm, 100 ppm, 150 ppm, 200 ppm, 250ppm, 300 ppm, 350 ppm and 400 ppm. Shimdzu Spectrophotometer (UV-120-01).

Test procedure.

1. The instrument was switched on and allowed to warm-up for ten minutes.
2. A wavelength of 370 nm was selected on the photometer.
3. The transmittance and absorbance were measured. A plot of absorbance and concentration was made (Appendix 2).
4. The range selection switch was set to 0 – 100% T and the lid of the sample compartment was opened, 0%T set was set with the 0%T knob.

5. The water sample in the cell was then placed in a cell holder after setting the digital panel meter reading to "000" with 100 %T/ZERO knob. The sample change knob was also set so as to insert the sample in to optical path.

6. The wavelength was set and the photometric value then read on the display panel. The concentration of calcium in ppm was then determined from the plotted graph in step (3). Steps 1- 6 were repeated in the determination of magnesium, sodium and potassium. Wavelengths of 350 nm, 330 nm and 380 nm were selected for magnesium, sodium and potassium respectively.

3.3.4 DETERMINATION OF METHYL ORANGE (HCO_3^-) ALKALINITY

Reagents and Apparatus

Sulphuric acid (H_2SO_3) 0.01M, methyl orange (indicator), burette (50ml capacity), two conical flasks (250ml) and measuring cylinder.

Test Procedure.

1. The burette was filled to mark with 0.01M sulphuric acid
2. 100ml of sample was measured into each of the flask.
3. To each of the flask two drops of methyl orange indicator was added.
4. The content of the flask was titrated with 0.01M sulphuric acid until a change in colour of titre was noticed.
5. The burette reading was recorded. The amount of sulphuric acid used for the titration gave the methyl orange alkalinity.

Total alkalinity was determined using equation (6)

$$M_{ilk} \text{ ppm } HCO_3 = \frac{\text{ml } 0.01M\ H_2SO_3 \times 100}{\text{Ml of sample}} \quad \text{-------------------(6)}$$

3.3.5 DETERMINATION OF SULPHATE (GRAVIMETRIC METHOD).

In the determination of sulphate gravimetrically, the sulphate was precipated as $BaSO_4$.

Reagents and Apparatus.

Dilute Hydrochloric acid, Barium Chloride solution, Silver Nitrate solution, evaporating dish (8cm diameter) and filter paper.

Test Procedure.

1. Sufficient water sample was taken and prepared to give a precipate of 85mg of Barium Sulphate.
2. Dilute hydrochloric acid was added to the precipitate to make the water just acidic.
3. The water was evaporated to 75ml.
4. Solution of Barium Chloride was added to the gently boiling sample and the obullition continued for five minutes. A coarse filterable precipitate of sulphate was obtained.
5. The precipitate was filtered off and washed with boiling water until the filtrate gave no turbidity when silver nitrate solution was added,
6. Precipitate and filter paper were gently ignited with the paper first being gently charred.

Calculation

1mg of $BaSO_4$ is equal to 0.411mg of SO_4^{2-}.

3.3.6 DETERMINATION OF NITRATE

Reagents and Apparatus.

Concentrated sulphuric acid (sg 1.83), Brucine solution, potassium nitrate solution, volume-trick flask (25ml) and Nessler Tube.

Procedure.

1. 10 ml of sample was measured into a Nessler tube and the same amount of distilled water into Nessler tube.
2. 0.5ml of brucine and 20ml concentrated sulphuric acid added to each of the Nessler tube.
3. The colour produced was measured against distilled water and the later appeared lighter.
4. The solution was titrated with potassium nitrate until the same colour match was obtained. Nitrate was then determined using equation (7).

$$NO_3^- \text{ ppm} = \frac{\text{ml of } KNO_3 \times 0.1 \times 100}{\text{ml of sample}} \quad \text{———————} (7)$$

3.3.7 DETERMINATION OF CHLORIDE (MOHR TITRATION)

Reagents and Apparatus

Standard silver nitrate (0.01M), potassium chromate (indicator), conical flask (250ml), measuring cylinder (100ml), pipette (25ml) and burette (50ml).

Procedure.

1. The burette was filled with standard silver nitrate solution ($AgNO_3$) to mark.
2. 100ml of sample was measured into 250ml conical flask and 1ml potassium chromate solution was added.
3. The sample was titrated with silver nitrate solution ($AgNO_3$) until pinkish yellow endpoint was obtained.
4. Burette reading was taken.

Chloride (ppm) was calculated using equation (8).

$$\text{Chloride ppm} = \frac{\text{ml } AgNO_3}{\text{ml of sample}} \times 100 \quad \text{----------------(8)}$$

3.3.8 SODIUM ALKALINIZATION

The risk of sodium alkalinization was measured as a ratio, which shows the extent of the replacement of calcium and magnesium ions by sodium ions at the soil exchange sites. The expression given below (Equation 7) described by Schwab et al (1971), Michael (1978), Hamill and Bell (1986) and presented by Raji (1990) was used.

$$SAR = \frac{Na}{[(Ca + Mg)/2]^{1/2}} \quad \text{--------------------- (9)}$$

where SAR is the sodium adsorption ration, Na^{+} the concentration of sodium ions in the water (Meq 1l), Ca^{2+} and Mg^{2+}, the concentrations of calcium and magnesium ions in the water (Meq /l).

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Soil Texture

The texture of the surface soil as well as the subsoil are good for irrigation. The texture varied from loamy sand of Edozhigi, Bida and Majingari to sandy loams of Agaie and Kudogi, in the top soils but with increasing clay content down the soil profile to constitute an argillic horizon (Table 1 and Appendix 3). Texturally therefore, the basement complex soils of Gbako drainage basin have adequate clay content particularly in the subsoil for enhanced soil moisture retention and soil productivity.

Table 1: Results of Particle Size Analysis at Gbako Drainage Basin

Area Sampled	Soil Depth (cm)	% Clay	% Silt	% Sand	Textural Class*
	0 – 15	10.7	10.0	79.3	LS
Edozhigi	15 – 30	11.3	8.7	80.0	LS
	30 – 60	15.4	11.3	73.3	SL
	0 – 15	10.0	6.7	83.3	LS
Bida	15 – 30	12.0	8.0	80.0	LS
	30 – 60	16.7	4.7	78.6	SL
	0 – 15	12.0	4.7	83.3	LS
Majingari	15 – 30	16.0	7.3	76.7	SL
	30 – 60	8.0	5.3	86.7	S
	0 – 15	9.8	18.5	71.7	SL
Agaie	15 – 30	10.6	14.9	74.5	SL
	30 – 60	19.8	10.0	70.2	SL
	0 – 15	10.0	33.3	65.7	SL
Kudogi	15 – 30	13.3	26.7	60.0	SL
	30 – 60	18.7	23.3	58.0	SL

* S = Sand, SL = Sandy Loam, LS = Loamy Sand

The percentage sand composition of soils in this basin is high, hence the permeability of the soil is therefore expected to be high and the internal drainage adequate. A high permeability is essential for leading down excessive salts or removal of sodium alkaline soil.

The good soil permeability would make it easy to supply the crop with water and greatly aid cropping in this area, as such problems like crushing of seedbeds, water logging of surface soil and accompanying disease, salinity, etc can be avoided. The soils are low in clay, hence deflocculation normally associated with sodium adsorption is expected to be minimal.

4.2 Groundwater.

From Table 2 all the sampled points of the research area have pH values less than 7 and hence could be regarded as acidic, since these values fall between 5 and 7 which is considered adequate for nutrient availability. The pH of waters sampled are therefore favourable for crop production.

Table 2: Chemical Characteristics of Groundwater in Gbako Drainage Basin.

	EDOZHIGI	BIDA	MAJINGARI	AGAIE	KUDOGI	UNIT
PH	6.4	6.2	6.4	6.5	6.8	
EC	1.57×10^2	1.0×10^2	2.5×10^2	1.6×10^2	2.52×10^2	µmhos/cm
TDS	261.37	240.13	410.52	272.07	168.0	ppm
Ca^{2+}	21.42	33.30	24.56	42.90	49.05	ppm
Mg^{2+}	27.19	18.52	38.20	14.86	23.26	ppm
Na^+	24.42	1.86	2.19	2.74	1.76	ppm
K^+	41.0	46.65	54.13	13.26	60.32	ppm
CL^-	1.35	1.81	3.21	7.32	12.82	ppm
SO_4^{2-}	5.23	4.99	7.96	6.74	9.64	ppm
NO_3^-	0.73	0.68	0.80	0.56	1.07	ppm
HCO_3^-	56.03	45.63	70.15	31.53	67.00	ppm

4.3 Salinity Hazard.

The salinity hazard was estimated by measuring the electrical conductivity (EC) of the water in micromhos per centimeter at 25 ^{o}C. EC values vary from 100 µmhos per centimeter to 252 µmhos per centimeter. The water within the basin present no problem as the salinity problem relating to water quality does not occur since the total quantity of salts in the groundwater within the basin is low (Tables 2 and 3). The values compared favourably with FAO guidelines and Dupriez and Leener limits (Tables 4 and 5) respectively. This water can therefore be used for irrigation with most crops on most soils with the likelihood that a salinity problem will develop. However, some leaching is required, but this is expected to occur under normal irrigation practices since soil in this area is of high permeability.

Table 3: Summary of Sodium Adsorption Ratio (SAR), Salinity and Water Class.

Location	SAR	Soil Texture	Salinity Hazard	Water quality Class
Edozhigi	0.08	Loamy sand	Low	Good ($C_1 - S_1$)
Bida	0.06	Loamy sand	Low	Good ($C_1 - S_1$)
Majingari	0.07	Loamy sand	Low	Good ($C_1 - S_1$)
Agaie	0.09	Sandy loam	Medium	Fair ($C_2 - S_1$)
Kudogi	0.06	Sandy loam	Low	Good ($C_1 - S_1$)
Average	0.072 Low	Loamy sand-Sandy loam	Low 100 – 250 μmhos/cm	Good ($C_1 - S_1$)

Table 4: FAO Guidelines for Irrigation Water Quality Appraisal
(Abstracted from FAO, 1976).

Hazard	Diagnostic Parameter	Criteria		
		No Problem	Moderate Problem	Severe Problem
Salinity	EC-Irrigation water (EC_i in mm hos/cm)	< 0.75	0.75 – 3.0	>3.0
Sodicity	EC-Irrigation water (EC_i in mm hos/cm)	>0.5	0.5 – 0.2	< 0.2
	SAR_i adj (irrigation water)			
	- Montmorillonite (2:1 clays)	< 6	6 – 9	>9
	- Illite/Verniculite (2:1 clays)	<8	8 – 16	>16
	- Kaolinte /Sesqui Oxide (1:1 clays)	<16	16 – 24	>24
Toxicity	(For sensitive crops only)			
	- Sodium: SAR_i adj (irrigation water)	<3	3 – 9	>9
	-Chloride:Cl concentration in irrigation water (Meq/l)	<4	4 - 10	>10
	- Boron: B concentration in irrigation water (Meq/l)	<0.75	0.75 - 2	>2

Source : Smedema and Rycroft (1988)

Table 5: Conductivity of Irrigation Water and of Water for Human Consumption.

	Conductivity (mm hos/cm)	Salinity (gram/litre)	Quality of water
For farm use	0 – 0.5	0 – 0.32	Good
	0.5 – 2.2	0.32 – 1.4	Average to poor
	>2.2	>1.4	Unsuitable for irrigation
For human consumption	0 – 0.4	0 – 0.25	Good
	0.4 - 0.75	0.25 – 0.5	Average
	0.75 – 1.0	0.5 – 1.0	Poor
	>1.0	>1.0	Unfit for consumption

Source: Dupriez and Leener (1992).

4.4 Sodicity Hazard

Sodium hazard sometimes exists in that sodium in irrigation water can bring about a eduction in soil permeability and cause the soil to harden. The risk of sodium alkalinization as neasured by the sodium adsorption ratio (Table 3) is extremely low and by far less than the imits of the low sodium water. Low sodium water can be used for irrigation on almost all soils vith little danger of the development of harmful levels of exchangeable sodium. However, Hamill and Bell (1986) reported that sodium sensitive crop such as stone fruit trees and ıvocado may accumulate injurious concentration of sodium. The sodium adsorption ratio (SAR) values within the basin vary from 0.06 to 0.09. Therefore, the groundwater within the basin based on the binomial classification of USSSL staff, falls within the "good class" ($C_1 - S_1$), Table3 and Figure 2. This implies that the groundwater can be used on soils of moderate to good permeability or for low salt tolerant crops or both, under careful farm management.

4.5 Toxicity Hazard

A toxicity problem occurs when certain constituents in the water are taken up by the crop and accumulate in amounts that result in reduced yield (Michael, 1978). This is usually related to one or more specific ions in water, namely, boron, chloride and sodium. There is no problem with water in the drainage basin. The concentrations vary from 1.86 to 2.74 ppm and 1.35 to 12.82 ppm respectively (Table 2). Sodium and Chloride concentrations of these ions are adequate for sensitive crops, which can be grown in the area. However, conditions which aggravate toxicity (such as the adoption of long irrigation intervals leading to advanced soil drying, under irrigation, etc) should be avoided.

4.6 Total Dissolved Solid (TDS).

The concentration of the total dissolved solid (TDS) ranges from 168 ppm to 410.52 ppm (Table 2). These values are average, and thus, the turbidity level which would have

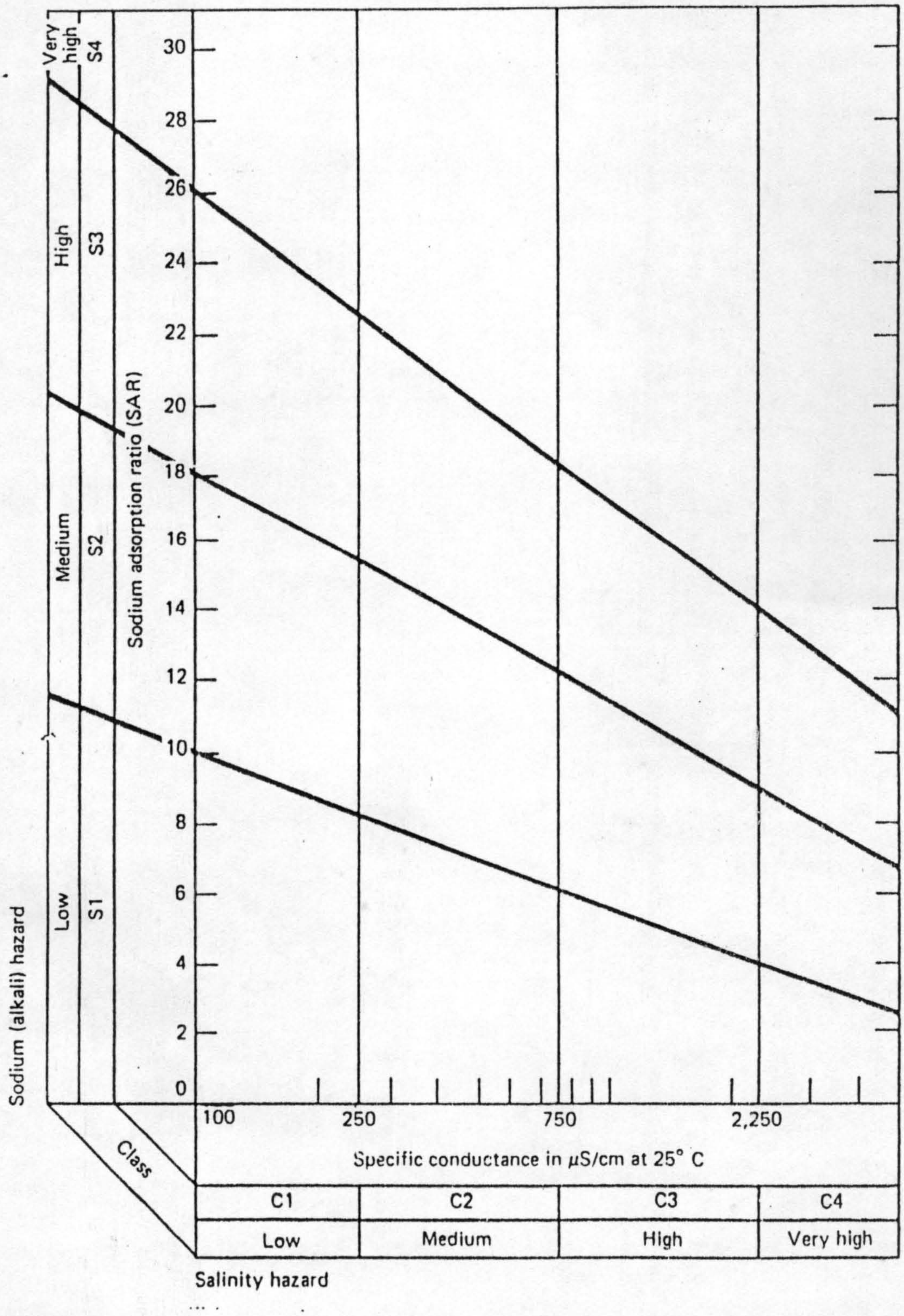

Figure 1. Classification of Quality Criteria for Irrigation Water (USSSL, 1954).

Source: Hamill and Bell (1986).

inhibited effective plant growth and development is low, hence the water quality is classified average for the purpose it is serving.

Considering the FAO and WHO standards (Tables 4 and 6), the concentrations of the various ions are well within the permissible limits. However, a slight increase in potassium and nitrate concentrations observed in Majingari and Kudogi can be attributed to the inorganic fertilizers used by the farmers in these areas. From the agricultural viewpoint, the quality of the groundwater within the basin is good and can be used for irrigation without any form of treatment. The good drainage of the top soils, and the moderate and evenly distributed rainfall will guarantee the proper leaching of any salt in the soil.

Table 6: International Standard for Irrigation Water
(After World Health Organization, 1958)

Na^+	SO_4^{2-}	CL^-	HCO_3^-	pH	TDS	Unit
50	200	100	200	4	500	ppm
-	-	-	-	-	-	-
200	400	250	400	9	9	ppm

Source: Raji (1990)

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

There is a little variation in the quality of the groundwater within the basin. The difference in the quality is of little or no significance to irrigation. The salinity hazard estimated by measuring electrical conductivity (EC) and sodium hazard measured as sodium adsorption ratio (SAR) gave low risk of salinity and sodium alkalization. The bicarbonate content is low, hence, the risk of precipitation of calcium and magnesium in the soil as insoluble carbonates is low. It is obvious therefore, that the groundwater under investigation is suitable and economical for irrigation purposes. Since the 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 any salinity at the root zone is kept to the minimum.

5.2 RECOMMENDATION

Based on the results of this study, the following recommendations are made:

i. It has been shown that groundwater within the basin can be used for irrigation with most crops on most soils. However, various other problems related to irrigation water quality occur with sufficient frequency and should be specifically noted. These include excessive vegetation growth, logging and delayed crop maturity resulting from excessive nitrogen in the water supply, etc.

ii. It was observed by Michael (1978) that the continuous use of irrigation water, with EC values greater than 750 μ m hos cm^{-1}, even on sandy soils is likely to develop a saline problem if adequate drainage is not ensured. It is therefore advisable that drainage and proper leaching of salts should be observed within the drainage basin. In addition, carbonates and gypsum could be added to improve upon its quality.

iii. Old method of enriching the soil fertility with manure from plant or animal should be re-modified and practiced by farmers in this area. This can reduce the effect of inorganic fertilizers on groundwater.

iv. Research should be carried out together with farmers in this area so as to establish some agricultural practices on the use of inorganic fertilizer. Such practices include control application rate, examination of nutrient and application rate annually before planting season and maximize the alignment between agricultural productivity and maintenance of environmental quality as being practiced in some countries.

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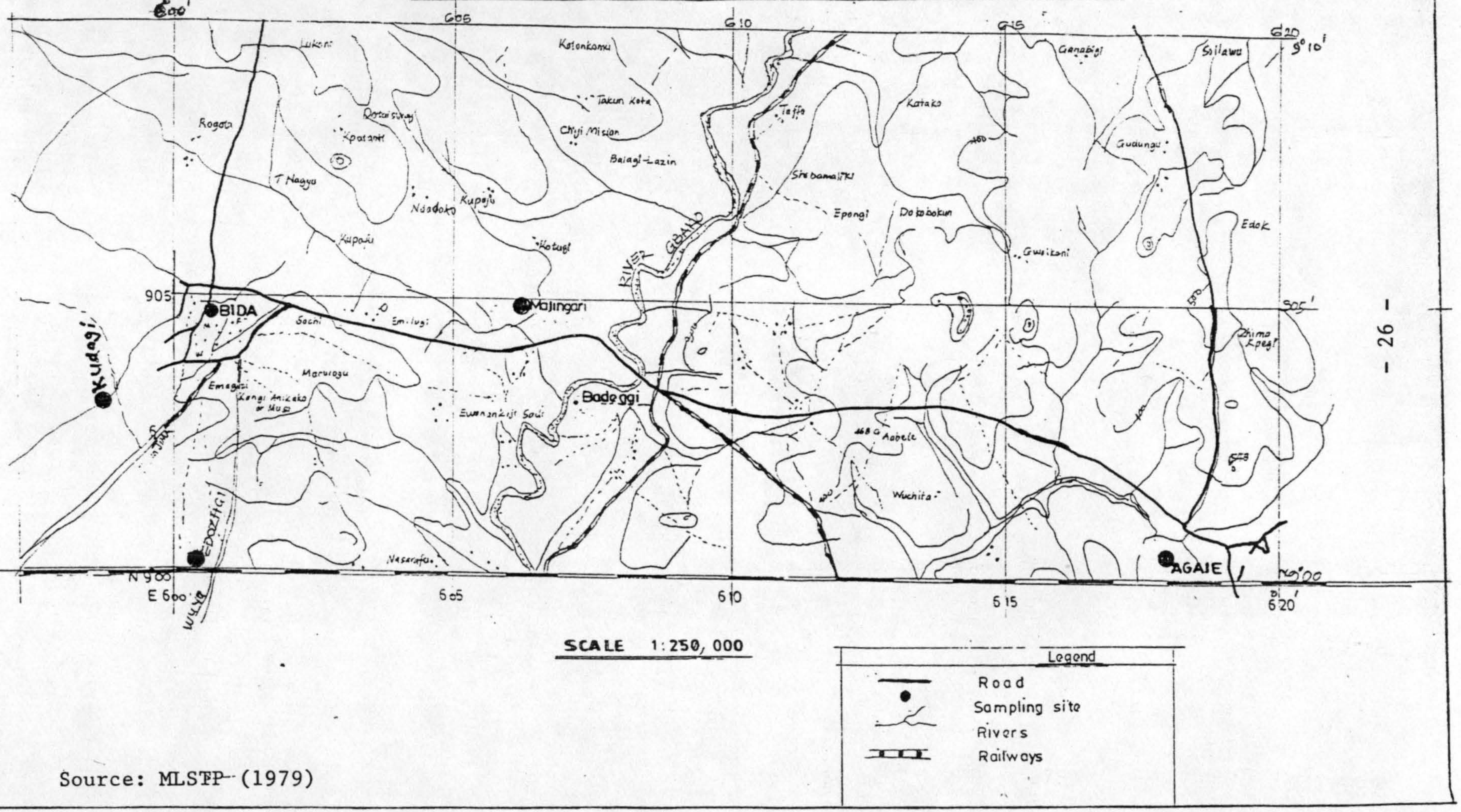
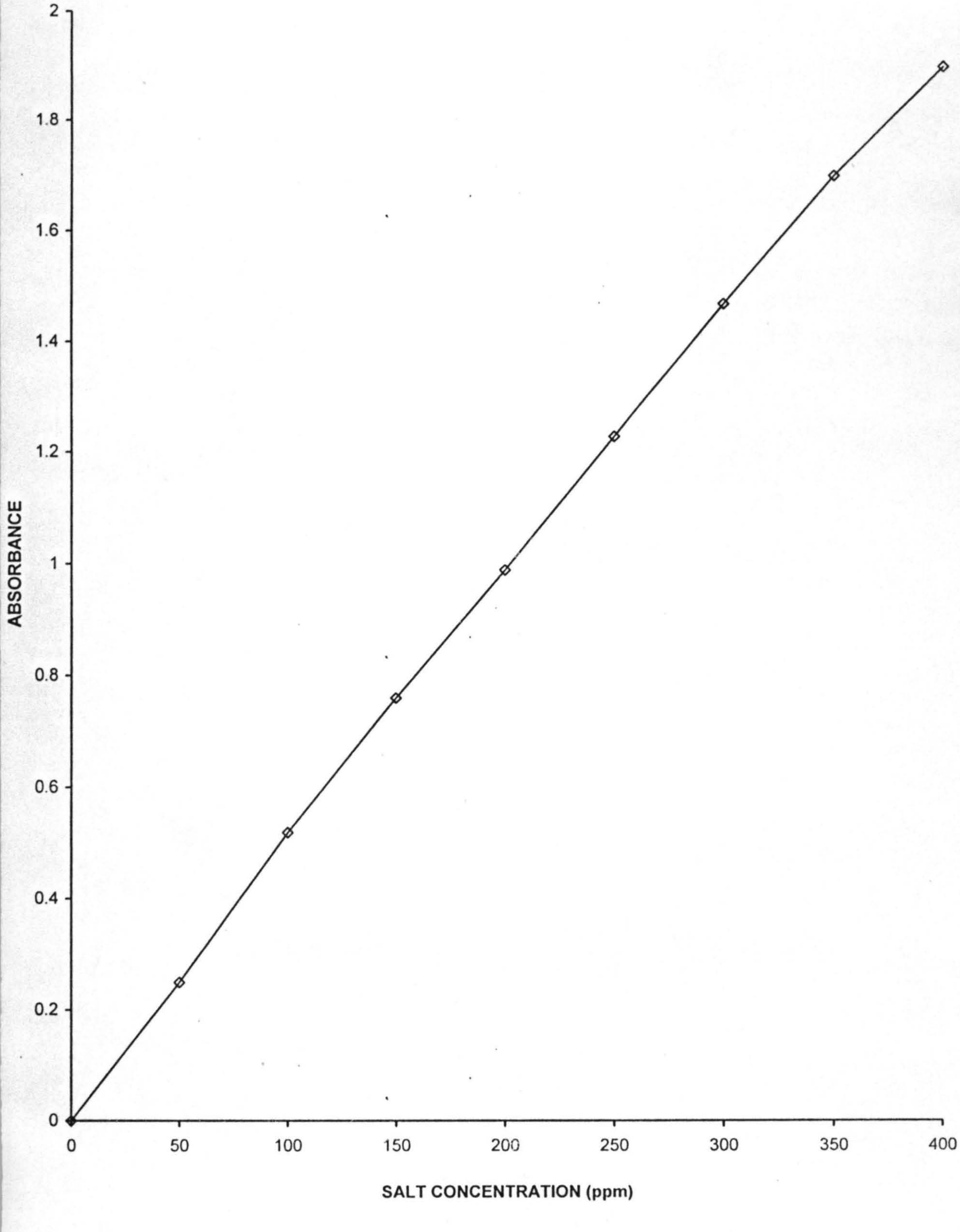
APPENDIX I

RESEARCH AREA (GBAKO DRAINAGE BASIN)



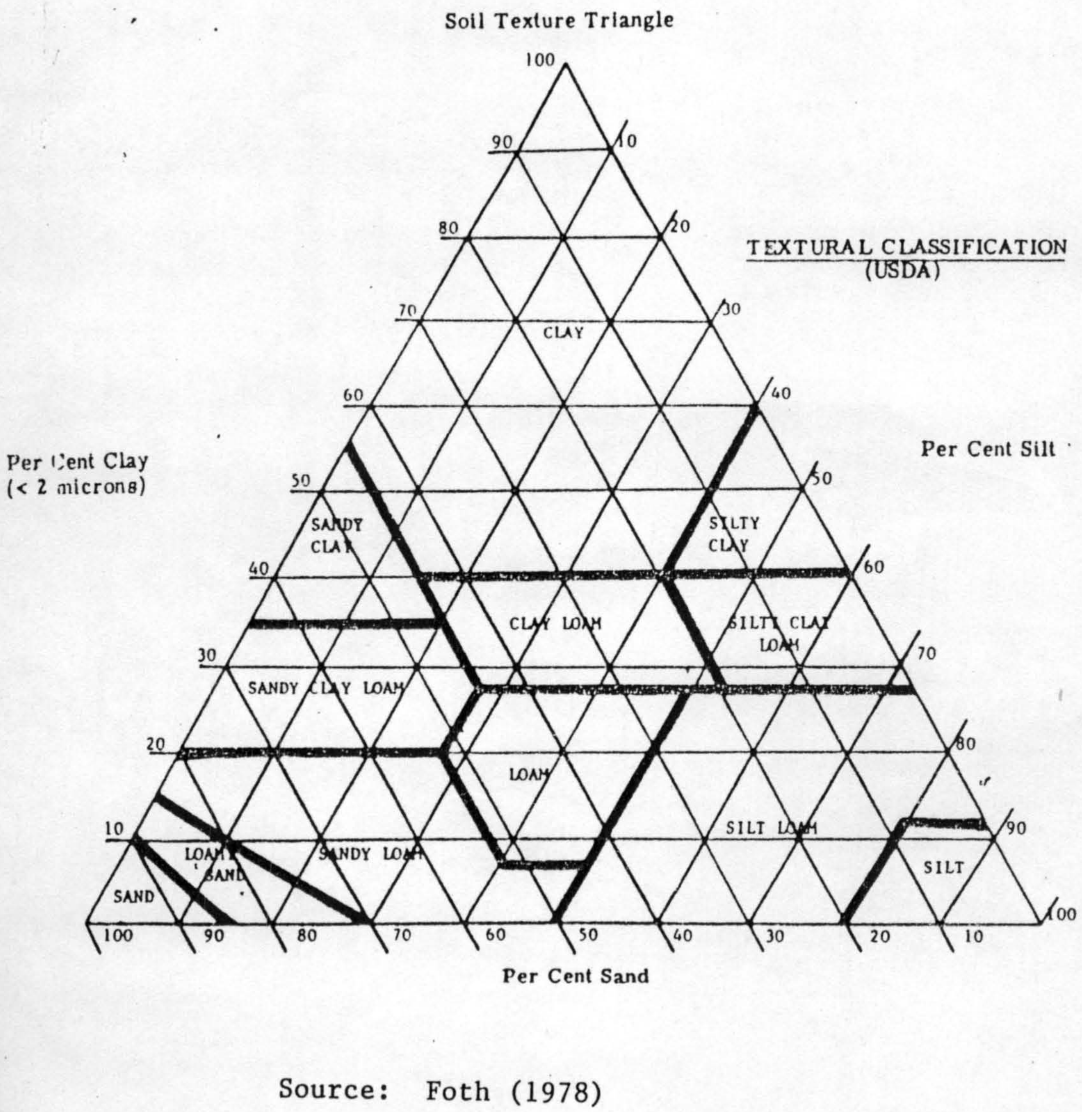
Source: MLSTP (1979)

Appendix 2.



Plot of Absorbance Against Concentration (ppm) for Calcium.

APPENDIX 3



Source: Foth (1978)