AN ASSESSMENT OF GROUND WATER QUALITY FOR SMALL-SCALE IRRIGATION IN THE SOUTHWESTERN SOKOTO RIMA BASIN, NIGERIA

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DECLARATION

"I hereby declare that this work is the product of my research effort undertaken under the supervision of the Prof. A.I. Tanko and has not been presented anywhere for the award of a degree or certificate. All sources have been duly acknowledge"

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CERTIFICATION

This is to certify that the research work for this dissertation and the subsequent write up by Abdullahi Bashar Kaoje SPS/11/MGE/00074 were carried out under my supervision

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DEDICATION

I dedicate this research to my parents; Alhaji Bashar Ahmed Muhammad and Late Malama Hauwau Bappa Adamu.

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ABSTRACT

Ground water from tube-wells were investigated to ascertain the current quality status and suitability for irrigation in the flood plains (Fadama lands) of the southwestern Sokoto-River Basin. Twenty water samples were collected. The Fadama areas have been divided into Fadama Users Association by Kebbi Agricultural Development Project. For this study, twenty Fadama Users Association were randomly choosen, they are: Huda, Mangoron Jega, Unguwar Dan Nana, Gulumbe, Alwasa, Bayawa Getare, Illelar Garbi, Kimba, Zauro, Kiyaki, Kurmi, Kardi, Matan Fada, Basaura, Bubuce, Dangmaji, Farfajiya, Tiggir, Galbi and Asarara. From each Fadama Users Association (FUA), one randomly selected tube well was sampled. Tube well was pumped out for at least twenty (20) minutes before sampling to ensure that the sample represented the water from the aquifer. Fourteen water quality parameters namely pH, Electrical conductivity, dissolve solid, Biochemical oxygen demand, Carbonate, etc, were analysed. The water samples were slightly acidic with pH values ranging from 5.7 to 6.3. In terms of salinity hazards measured as electrical conductivity (EC) and concentration of basic cations, the overall means for Calcium, Magnesium and Sodium respectively were 1.834, 2.13, 2.635 and 1.985 mg. substantially higher concentration of Magnesium and Phosphate in irrigation water suggests that it contains a lot of salts, excessive irrigation with such water will lead to soil salinization. Pearsons product moment correlation matrix and principal component analysis (PCA) were used to distinguish the main pollution sources in the Rima Basin. Five varimax were extracted from PCA which explained 77.7% of the variation. Hierarchical cluster analysis (CA) grouped the sampling points into three clusters based on the similarities of tube well water characteristics. Cluster I represents less polluted sites, these stations receives pollution from mostly rural waste water and Agricultural activities. Cluster II and III corresponds to highly polluted sites. Discharge of domestic waste, grazing, fertilizer, irrigation water, flushed pollutants from crops, leached pollutants from soil, animal waste, pesticides and other agricultural chemicals.

CHAPTER ONE

INTRODUCTION

1.1 Background

Ground water is considered as one of the purest terms of water available in nature and meet the overall demand of uses as well as water population. With the growth of industry the ground water is made susceptible for contamination due to adding of waste materials. Waste materials from the factories percolate with rain water and reach aquifer resulting in erosion of ground water quality.

Ground water is used for domestic, industrial, water supply and irrigation all over the world. In the last few decades, there has been a tremendous increase in the demand of fresh water due to rapid growth of population, unplanned urbanization, industrialization and too much use of fertilizer and pesticides in agriculture (Joader et al., 2008). Ground water meets domestic needs of more than 80% rural and 50% urban population besides irrigation.

Over exploitation of ground water through the one well and their in proper handling resulted in very low ground water level besides contamination of every bare water at some places. The addition of various kinds of pollutant and nutrients through the agency sewage, industries, agricultural run off etc; in to the water bodies leaving about series of change in the physiochemical characteristics of water, which has been the subject of several investigations (Mahananda et al., 2010). The availability of ground water depends upon the rate at which it is recycled by the hydrological cycle than on the amount that is available for use at any moment in time. Once the ground water is contaminated, its quality cannot be restored back easily and to device ways and means to protect it

(Maniyar, 1990) An understanding of water chemistry is the bases of the knowledge of the multidimensional aspect of aquatic environmental chemistry which involves the sources, composition reactions and transportation of water.

Water resources form one of the most important physical land resources in arid and arid areas where irrigated agriculture is taking place. The quality and quantity of the water supply are equally important as soil and other factors to the successes of an irrigated project. Water quality and quantity was considered as important criteria to be evaluated for all land utilization types, therefore it was considered as a crop factor that determines land suitability class in FAO Guidelines of Land Evaluation (FAO, 1985).

Irrigated agriculture is dependent on an adequate water supply of usable quality. Water quality concerns have often been neglected because good quality water supplies have been plentiful and readily available. This situation is now changing in many areas (Ayers and Westcot, 1985). Conceptually, water quality refers to the characteristics of a water supply that will influence its suitability for a specific use. Quality is defined by certain physical, chemical and biological characteristics. In irrigation water evaluation, emphasis is placed on the chemical and physical characteristics of the water and only rarely are any other factor considered important (Sargaonkar and Deshpande, 2003, Ayers and Westcot, 1985).

A major objective of water quality assessment for irrigation is to determine whether the water quality meets the objectives of irrigation for use in agriculture; to describe water quality on regional or national scales; and also to investigate change of quality in time.

The overall suitability of water for irrigation depends upon:

1) The nature of the soil.
2) Crops tolerance to salinity of various types of irrigation water and
3) Water quality and the management of irrigation practices.

Water quality criteria must be interpreted in the context of overall salt balances and toxicities and the effects on soil. It is commonly accepted that the problems originating from irrigation water quality vary in type and severity as a function of numerous factors including the types of the soil and the crop, the climate of the area as well as the farmer who utilizes the water. According to Ayers and Westcot (1985), there is now a common trend that these problems can be categorized into the following major groups:

1) Salinity hazard
2) Infiltration and permeability problems
3) Toxicity hazard
4) Miscellaneous problems.

The toxicity hazard can further be grouped into problems associated with specific ions as well as hazards related to the presence of trace elements and heavy metals.

Traditional approaches to assessing water quality are based on a comparison of experimentally determined parameters value with existing guidelines. In many cases, the use of this methodology allows proper identification of limitation sources. The quality of irrigation water therefore generally influence the total yields obtained, where irrigated agriculture is practiced, as water is critical for the growth and development of plants.

U.S. STATEMENT OF RESEARCH PROBLEM

In semi arid areas of the world, Northwestern Nigeria inclusive, rainfall is often inadequate in amount and erratic in timing; thus necessitating irrigation in order to satisfy

the moisture requirement of the crops needed to meet the demands for food and fibre (Michael, 1978).

According to Michael, (1985), irrigation water, irrespective of its source, contains some dissolved salts. The quality and nature of these dissolved salts depends on the source and chemical composition, which in turn is influenced by hydro meteorological conditions (Belan, 1985).

The most commonly dissolved ions in water are Calcium, Magnesium, Sulphate, Sodium, nitrite, baron, chloride, carbonate. It is the concentration and proportion of these dissolved ions among other things that determine the suitability of water for irrigation (Housen, 1980; Belan, 1985 and Ajayi,et al 1990). Problem known to be associated with high concentration of soluble salts in irrigation water include salinity and toxicity effects of the individual ions, impaired seed germination and seedling growth. They also have effects on soil physical properties. It is therefore obvious that the quality of irrigation water is one of the principal considerations in irrigation planning.

The Southwestern of Sokoto Rima Basin has a Semi –Arid climate with water posing the most serious constraint to agricultural production. This reality informed the setting up of irrigation scheme in the basin (Anonymous, 1993). Information on the quality of water used in the scheme was lacking. Most attention has always been given to the availability of water, while the correlations between the quantitative and qualitative aspects of water management are overlooked (Water Resource Institute, 1986). The quality implication of water resources management is more critical in semi – arid areas as they are more prone to natural sources of pollution such as salinization. Due to the higher water requirement of crop, the degree of exploitation of water resources will usually be higher with the

consequent acceleration of the processes of salinization of water resources (Werner, 1980, as cited in Shural, 1980). The foregoing therefore highlighted the need to acquire data on the characteristics of water used in the scheme as well as to keep following its changes over time. The study is therefore aimed at investigating the □hysic-chemical characteristics of the water used in the Southwestern Rima Basin with a view to ascertaining its suitability or otherwise for irrigation.

U.S. **AIM AND OBJECTIVES**

The aim of the study is to asses the current quality status of irrigation water from tube-wells used for small scale Fadama farming. The research will pursue the following objectives:

i) To determine the □hysic-chemical status of the groundwater used for irrigation.
ii) To compare the result obtained with National and International set standard for irrigation.

1.4 SCOPE OF THE STUDY

The study focuses on physical and chemical parameters of tube-wells water that have impact on irrigation agriculture. The study area where the sample will be collected, is Fadama irrigation area within the Southwest Sokoto Rima basin particularly the zone one according to the Kebbi Agricultural Development Project (Argungu Zone) .

The Physicochemical parameters to be considered are pH, electrical conductivity, dissolved solid, biochemical oxygen demand, carbonates, bicarbonates, chloride, sodium, nitrates, phosphates, potassium, magnesium, total dissolved solid and suspended solid.

1.5 JUSTIFICATION OF THE STUDY

To ensure efficient exploitation of the potentialities of Fadama land, the Federal Government of Nigeria with assistance from the World Bank embarked on the National Fadama Development Project (NFDP). The NFDP aims at developing the Fadama lands for sustainable Agricultural production all the year around through small-scale irrigation with underground water. For this work, a network of tube wells and/or wash bores have been established within the Fadama land throughout the state.

However, the suitability of life wells water for irrigation, depends largely on its quality. From the Agricultural viewpoint, the use of good quality water for irrigation is very essential. Use of low quality water for irrigation coupled with semiarid weather conditions makes the Fadama irrigated soils prone to salinity/sodality development and consequent hazards. The findings of this research work is going to be useful to both government/policy maker and farmers in the water quality management for the former and selection of suitable crops for the later.

1.6 CONCEPTUAL FRAME

1.6.1WATER QUALITY

This study is situated within the general frame of water quality. Water quality perfoms important role in health of human and animals and plants. The quality of surface water within a region is generally both natural processes (such as precipitation rate, weathering processes and soil erosion) and anthropogenic effects (such as urban industrial and agricultural activities and human exploitation of water resources) (Jarvie, et al ,1998; Liao, et al,2007; Mahvie, at al, 2005; Nouri, et al, 2008).

The anthropogenic discharges constitute a constant polluting source where as surface runoff is a seasonal phenomenon largely affected by climate within the basin (Karbassi, et al, 2007; Najipour, et al,2008; Sign, et al,2004). Seasonal variation in precipitation, surface rainoff, ground water flow, interception and abstraction is strongly affects river discharge and consequently the concentration of pollutants in river water (Khadkha and Khanal, 2008; Mtethiwa., et al,2008)

Human activities are a major factor determining the quality of the surface and ground water through atmospheric pollution , effluent discharges, use of agricultural chemicals, eroded soils and land use (Niemi, et al, 1990). These land use changes increase the amount of impervious surface resulting in storm runoff events that negatively affects water quality (Parel, et al, 2001).

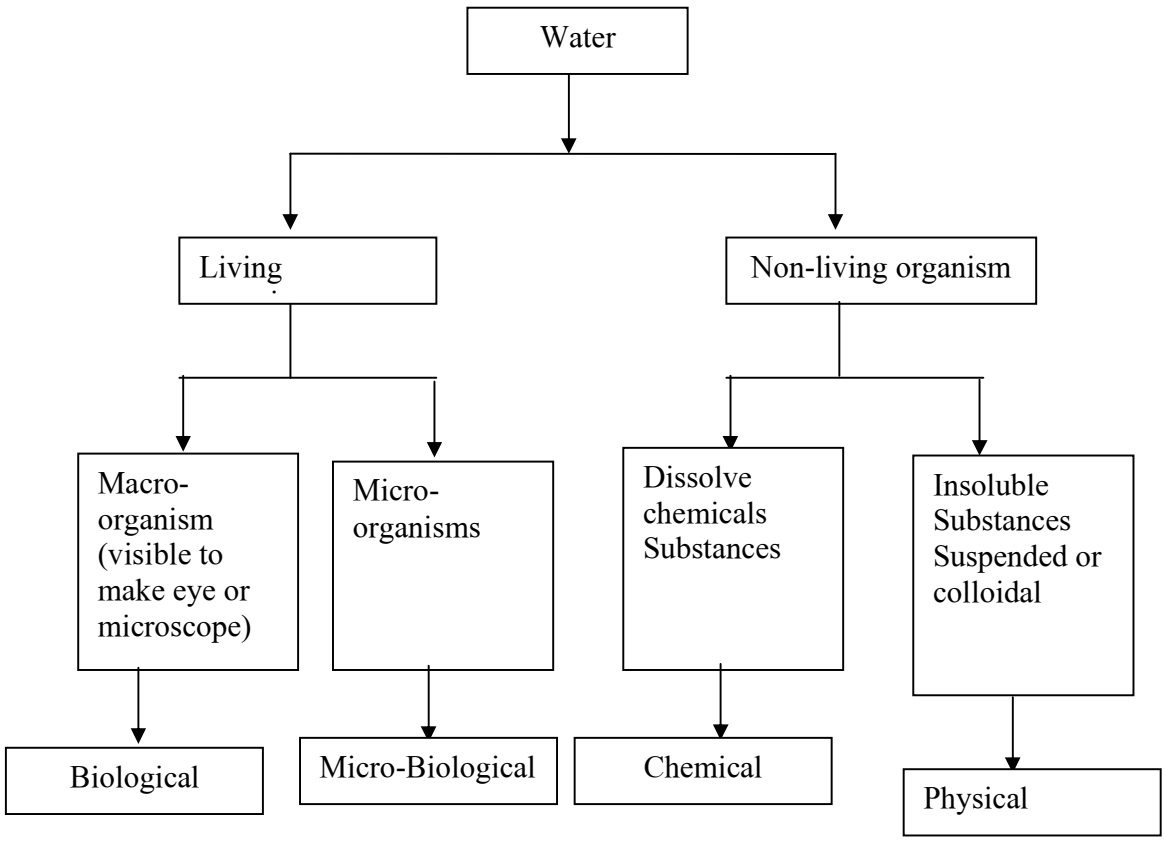


Figure 1.1 Factors determining Water Quality (After RAIN, 2008)

It is difficult to find completely pure water in nature. Rainwater that reaches the earth acquires range of substance in the atmosphere as well as living organisms through air born dust particles (Thomas and Martinson, 2007; RAIN, 2008). These substances and organisms affect composition of the water and their levels in water determine acceptability of quality.

Acceptability or otherwise of water quality is done by reference to a set of standards used to assess water quality relate to drinking water, safety of human contact and for the health of ecosystem (WHO, 2008; Diesing, 2009).

WATER QUALITY STANDARD

Water is being considered as food, as such it must be provided to consumers in good quality i.e. in a safe manner that is unlikely to cause physical harm through consumption. The HOW guideline for drinking water defined safe drinking water as the one that does not represent any significant risk to health over a lifetime of consumption, including different sensitivities that may occur between life stage (WHO, 2008). The WHO guideline are intended to support the development and implication of risk management strategies that will ensure the safety of drinking water supplies through the control of hazardous constitutions of water. The guidelines describe reasonable minimum requirements of safe practice to protect the health of consumers and or derive numerical "guideline values" for constitutions of water or indicators of water quality. It is from these scientific basis that national standards are developed, taking into account when setting mandatory limits, the local or national environmental, economic and cultural conditions.

Taking into considered the WHO guidelines, the standards organization of Nigeria (SON) in collaboration with concerned stakeholders came up with the Nigerian standard for Drinking water Quality, which was last revised in 2007. The standard contains mandatory limits concerning constitutions and contaminants from consumers. The standard includes a set of procedures and good practices required to meet the mandatory limits (SON, 2007)

1.7 LITERATURE REVIEW

Physico- chemical characteristics of water:

1.7.1 pH

On assessing the ground water quality in Nigeria and abroad, many workers detected the pH as one of the important parameter

Singh (2000) recorded the pH range for tube wells as 6.1 – 70(mean 67) Du preez (1961) cited in Singh (2000) reputed pH 6.5-8.8 for the underground water in Nigerian Basement complex. While Roose and Lelong (1981) cited in Singh (2000) obtain mean pH of 6.7 for the West Africa ground water. Ibrahim, et al (2000) reported pH mean of 7.4 for the surface and ground water in Goronyo and Wurno irrigation project. Singh (2000) recorded the pH for tube well water in Fadama land of Sokoto state as 5.4-7.7 with the over mean of 6.5. Graham (2006) reported a pH value falling within the range of 5.7 and 6.1 for the surface and ground water in the South West Sokoto Rima Basin. Sanda and Samson (2014) reported pH 6.9-7.1 for surface and ground water in flood plain of Jega Kebbi state. Ajon et al (2012) reported the pH range for surface water of river Kastina-ala catchment in Benue state as 6.6-83 (mean 7.3) 9(Adamu 2013) recorded the pH range 7.10 to 7.50 for surface water in Wutari irrigation project. Danko (1997) reported the

mean pH ranging form 7.9-8.3 for surface within along river in Sokoto state. George (2013) also obtain pH value which range 6.65-10.00.

Patil *et. Al*., (2001) noted the pH of ground water in Ganesh colony Jalgaon city and found that water samples were slightly alkaline with pH varying from 7.29 to 7.5.

Lone *et. Al*., (2003) recorded the pH of sewage water and tube well water from Hassanabdal area district Attock was 7.6 and 7.8 respectively. Unnisa and Khalilullah (2004) recorded the pH of ground and surface water qualities in the Kattedan industrial area were found in the range of 6.5 to 7.5. It is evident from their study that pH values have not exceeded permissible limit according to WHO standard. Nair *et. Al*., (2005) recorded the pH of ground water samples from 4 stations of North- east Libya. The pH of the water was alkaline i.e. in the range of 7.7 to 8.9, Albayda and Shahat is 8.6 and Ras alhilal is 8.7 in Jebel al- Akdar exceeding the desirable limit. Murali and Rani (2005) recorded the pH of water samples varied from 6.81 to 7.8 from Jodugullapalem slum area of hysic riate . Majority of samples are slightly alkaline due to carbonates, bicarbonates of calcium and magnesium dissolved in water. Sial *et. Al*., (2005) recorded the pH of ground water samples of Faisalabad city. The pH of different treatments of water samples i.e. 100% ww, 50% ww, 100% cw were 7.5, 7.6 and 7.5. Quality of ground water in all the treatments was alkaline in nature. Nazif *et. Al*., (2006) noted the average pH of irrigation canal water of Akbarpura area, Pakistan ranged from 8.1 to 8.3 and that of Bara river ranged from 8.4 to 8.9. Minakshi *et. Al*., (2006) recorded p^H of ground water samples of Rupnagar district of Punjab were all alkaline in reaction and ranged from 7.69-9.24. Acharya *et. Al*., (2008) noted the pH of ground water in Bhiloda Taluka region, North Gujarat ranges between 8.0 to 9.4. The lowest value is observed in Jayla and the

highest in Retoda village. It is observed that 76% of the water samples lie in the range of 6.5 to 85 prescribed by Bureau of Indian standards. Akan et. Al.,(2008) recorded pH of Jakara wastewater of Kano state Nigeria ranges from 8.94 to 10.34. The mean pH values recorded for all the sampling point were above the WHO pH tolerance limit of between 6 to 9 for wastewater to be discharged into channel into stream. Wagh *et. Al.*, (2009) noted the pH of ground water in pravara area, district Ahmednagar, was in between 7.0 to 8.5. These values are in limit of ISI. Sonwane *et. Al.*, (2009) recorded the pH of ground water from Kurkumb industrial area, Daund, pune district ranges between 7.75 to 9.00. The observed variation may be due to leaching of effluent and excessive use of fertilizers in local agricultural operation. Pandey *et. Al.*, (2009) recorded the pH of ground water samples of Rupnagar district of Punjab were all alkaline in reaction and ranged from 7.69-9.24. Pandey and Tiwari (2009) recorded the pH value of ground water of selected area of Ghazipur city range among 6.8 to 8.3. It is in the prescribed limit of ICMR.

1.7.2 Temperature

Unnisa and Khalilullah (2004) recorded the mean temperature values of surface and ground water were 28.8^{o}C and 26.4^{o}C respectively from Kattedan industrial area. Minakshi *et. Al.*, (2006) noted the temperature of ground water samples of Rupnagar district of Punjab was 37.6^{o}C. Mishra and Bhatt (2008) recorded the temperature of ground water in V.V. Nagar and near by places of Anand district, Gujarat ranging from 28 to 31^{o}C. Akan *et. Al.*, (2008) the temperature of Jakara waste water of Kano state Nigeria varies from 31.11 to 36.34^{o}C. The results indicate that some reactions could be speeded up by the discharge of this wastewater into stream and also reduce solubility of

oxygen and amplified odour due to anaerobic reaction. These values were higher than WHO standard of 40^{o}C for discharged of wastewater into stream.

1.7.3 Electrical Conductivity

Singh *et al.* (2002) measured the conductance in the tub well water of Fadama and in Sokoto state in the range of 34-1233μScm^{-1} (mean 399μScm^{-1}) Singh (2000) recorded the EC of tube well water in Zamfara state was ranging between 498-5779μScm^{-1} (mean 1799μScm^{-1}) electrical conductivity ranged from 90 to 1250μScm^{-1} for surface water in Goronyo and Wurno irrigation project (Ibrahim et al 2000). Singh (2000) recorded EC of surface and ground water from Kebbi state ranged 10-1350μScm^{-1} (mean 177μScm^{-1}). The EC ranged 0.05 is 0.92 was recorded in water from the Kaduna poly demonstration farm (George 2003). Graham (2006) recorded EC ranges of 204-607μScm^{-1}, 88-822μScm^{-1} and 87-188μScm^{-1} reproductively open well, tube well and borehole water in South West touch Rima base.

The EC of surface and ground water of Rajangpur was in the range of 179 to 201 μScm^{-1} (Adak and Purohit, 2003). Nazif, et al, (2006) measured the conductance in the lake Surinsar (Jammu) in the range of 0.05 to 0.58 μScm^{-1} Koshy and Nayar (2000) measured the electrical conductance in river Pamba at Kozencherry in the range of 50 to 88 μScm^{-1}. It has been suggested that irrigation water having conductivity lower than 250 μScm^{-1} does not contain enough salts to be safe. The electrical conductivity values of ground water in Ganesh colony, Jalgaon city were in the range of 1138 and 390 μScm^{-1} for tube well and open well samples and the value of tap water was 358 μScm^{-1} that is in the

prescribed standard limit Ganguly and Maiti (2002) recorded EC of domestic sewage and well water samples of residential university campus of Dhabi, Jharkhand varies from to 1306 µmhoscm $^{-1}$ and 569 to 1336 µmhoscm^{-1} respectively. Rani *et. Al*., (2003) measured the conductivity of rural places in and around Thittagudi, Tamilnadu, with five river water samples from 0.83 to 1.54 µScm^{-1}. . Lone *et. Al*., (2003) reported the EC of sewage and tube well water of Hassanabdal area of district Attock was 3.2 and 0.2 dSm^{-1}. Varadarajan and Purandara (2003) reported the EC of Malaprabha sub-basin of Belgaum district, Karnataka varies between 60 to 3510 µmhoscm^{-1} during pre- monsoon and 36 to 3800 µmhoscm^{-1} during post monsoon season. It was observed that waters of high EC values are predominant with sodium and chloride ions.

Unnisa and Khalilullah (2004) recorded mean values of conductivity of ground and surface water of Kattedan industrial area was 1549.4 µScm^{-1} and 3099 uScm^{-1} respectively. The high EC was due to the high level of dissolved ionic substances. Singh (2004) recorded the EC of sewage water samples of southern Haryana ranged from 1.24 to 4.82 µSm^{-1}. The highest EC may be de to the addition of industrial wastewater to the sewer. Gupta *et. Al.,* (2004) recorded the conductivity values varies from 475 to 4215 scm^{-1} of ground water samples from Sanganer and surrounding area of Jaipur city in Rajasthan. The average value of conductance in the residential area was within the limit but the value in the industrial area was high. Achuthan Nair *et. Al*., (2005) recorded the average value of EC in the ground water of NE Libya µmhoscm^{-1}. The EC conductivity values observed were well above the standard desirable limit prescribed by WHO (1984). Murali and Rani (2005) noted the electrical conductivity of samples varied from 1.0 to 1.79 mmhoscm^{-1} of Jodugullapalem slum area Visakhapatnam. Changes in conductivity

of a sample may signal changes in mineral composition of raw water and intrusion of domestic wastewater. Sial *et. Al*., (2005) recorded the EC of ground water samples of Faisalabad city. Taking canal water (100% cw) as reference, the value of EC in 100% wastewater was more than double (4.6 dSm^{-1}) and 50% wastewater also indicated high value of EC (3.8 μSm^{-1}) that was nearly double compared to reference quality water S. Iqrar.Sial *et. Al*., (2005) recorded the EC of sewage water sample of Faisalabad ranged from 2.28 to 4.03 dsm^{-1}. Minakshi *et. Al*., (2006) recorded the EC of ground water samples of Rupnagar district of Punjab ranged from 0.13 to 0.75 dsm^{-1}. Nazif *et.al*., (2006) noted the average EC of irrigation canal water of Akbarpura area Pakistan ranged from 0.86 to 1.02 dSm^{-1} and that of Bara river ranged from 1.05 to 1.38 dSm^{-1}. All the water samples were found non-saline and will not contribute any harmful effect to agricultural land and crop.

Acharya *et. Al*., (2008) measured the electrical conductivity maximum in Sunokh (3442 $\mu mhoscm^{-1}$) and minimum at Jinava (231 $\mu mhoscm^{-1}$) of bore wells in Bhiloda taluka, North Gujarat. The result indicates that almost all the water samples are within the permissible limit of 25 $\mu mhoscm^{-1}$ Akan *et. Al*., (2008) recorded the EC of Jakara wastewater of Kano state Nigeria ranges from 1021.17 to 1534.21 μScm^{-1}. The mean conductivity values for all the sampling point were higher than the WHO guideline values of 1000 μScm^{-1} for the discharge of wastewater through channel into stream Wagh *et. Al*., (2009) recorded the maximum value of EC in pre monsoon season is 700 μScm^{-1} While minimum value at post monsoon season is 100 μScm^{-1} of ground water around Pravara area. The electrical conductivity values were higher than permissible limit

ranging between 250 to 750 μmohscm^{-1} for domestic use. Pande *et. Al*., (2009) recorded the EC of treated distillery effluent of Ghazipur city was 18 χ.

1.7.4 Total dissolved solids

Singh (2000a) recorded the range of total dissolve solid from 10-3250 with the mean (352mgk from the ground and surface water of water in Kebbi state. Singh (2000b) obtained recorded total dissolve solids content of tube well water in Zamfara state ranged from 12-19mgk with the total of 60mg/l.

The ranges of total dissolved solids from 87.3 to 190 mg/Land 168.97 to 442.0 mg/L in surface water and ground water respectively at Mandiakudar were recorded (Adak and Purohit, 2003). Ganguly and Maiti (2002) recorded the total dissolved content of domestic sewage and well water samples of University campus area Dhanbad, Jharkhand varies from 523 to 909 mg/L and 326 to 636 mg/L. The total dissolved solids (TDS) of sewage effluent from dry weather flow channel Calcutta were higher in winter than in monsoon and ranged from 60 to 580 mg|L during monsoon and from 50 to 1400 mg|L during winter. The total dissolved solids were within the maximum recommended limit (1500 mg|L) for land irrigation Sanganer area, Jaipur in Rajasthan ranged between 335 to 3280 mg/L. Due to high concentration of TDS in water, the ground water is not suitable for textile, paper and food industries. Unnisa and Khalilullah (2004) noted the mean the total dissolved solids of ground and surface water samples of Kattedan industrial area were 935.6 mg/L and 2680.6 mg/L respectively. The TDS values were higher than prescribed limits. So it is not fit for drinking purpose. Singh (2004) recorded the total dissolved solids of sewage water of Southern Haryana ranged from 400 to 5700 mg/L. were well above the prescribed limit by WHO. Sial *et. Al.,* (2005) recorded the TDS of

ground water samples of different irrigation treatments such as 100% ww, 50% ww and 100% cw and the values of TDS were 2542 mg/L, 200 mg/L and 1182 mg/L respectively. Akan *et. Al*., (2008) reported total dissolved solids content of Jakara wastewater of Kano state Nigeria varies from 2210.21 to 2655.43 mg/L. These values obtained for TDS in all the sampling points were higher than WHO standard of 2000 mg/L for the discharge of wastewater into surface stream.

1.7.5 Dissolved oxygen (DO)

Ibrahim et al (2000) recorded the dissolve oxygen mean value of 227.9mg/l for surface and ground in Goronyo and Wurno irrigation project.

Singh (2000) recorded the dissolved oxygen in the Osmansagar, Mir-Alam and Hussainsagar and the mean values were 8.36 mg/L, 8.38 mg/L, and 3.21mg/L respectively. The low value of dissolved oxygen Hussainsagar was due to indiscriminate release of domestic sewage and industrial effluents into it. Dutta *et. Al*., (2002) determined the dissolved oxygen in Bhillan spring water at Udhampur ranged from 1.8 to 5.0 mg/L. Seasonally dissolved oxygen remained low in rainy while high during summer season. The maximum dissolved oxygen content 13.60 mg/L and minimum 1.6 mg/L were recorded during the study period. The increased dissolved oxygen content was due to high temperature and increased productivity and organic matter utilization by microorganisms. Adhikari and Gupta (2002) observed the dissolved oxygen of sewage effluents from dry weather flow channel Calcutta and varied from 2.0 to 5.6 mg/L during monsoon Hussain and Ahmad (2002) determined the dissolved oxygen content of Pachin river water at Itanagar fluctuated from 5.0 to 12.5 mg/L. The decrease in dissolved oxygen was due to waste water discharge to the river from local streams. Abdul Jameel

(2002) observed the dissolved oxygen in water of Tiruchirapalli, Tamilnadu and varied from 2.0 to 4.2 mg/L. Pandey and Tiwari (2009) noted DO content of ground water of Ghazipur city ranged from 3.4 to 5.0 mg/L indicating the nearly pure symptoms.

1.7.6 Biochemical oxygen demand

Koshy and Nayar (2000) determined the water parameters in river Pamba at Kozencherry and found BOD values fluctuated between 4.8 mg/L and 8.1 mg/L. Ganguly and Maiti (2002) observed the BOD values of domestic sewage water ofUniversit campus area Dhanbad, Jharkhand ranged from 209 to 223 mg/L. Unnisa and Khalilullah (2004) reported mean BOD values of ground and surface water of Kattedan industrial area was 2.4 mg/L and 2110 mg/L respectively. The ground water samples have low values of BOD while surface water contains higher content of BOD due to organic material from decaying plant material or inlet of domestic or industrial wastes. . Akan *et. Al.*, (2008) recorded BOD content of Jakara wastewater of Kano state Nigeria ranged between 223.43 to 341.1 mg/L. The concentration of BOD in all the sampling points was higher than the WHO values of 50 mg/L for the discharged of wastewater into stream. The high BOD might be due to the use of chemicals, which are organic or inorganic that are oxygen demand in nature.

1.7.7 Bicarbonates

The ground water in Kebbi as well as surface water were discovered to have negative RSC value (Singh 2000a) indicating the negligible amount of bicarbonate. Ground water in Zamfara State had negative RSC value (Singh 2000b). But the surface water in Sokoto State from some water bodies contained some amount of Residual Sodium Carbonate (RSC) (Singh and Tsoho 2000). Du Preez (1961) cited in Singh, (2000) reported no

bicarbonate in the Nigerian basement complex. Singh and Tsoho (2000) opined that the surface water in Sokoto except that from Goronyo Dam had some amount of Residual Sodium Carbonate, though the value were quite low within the ranges of 0.01-0.28mg/l. Graham et al (2006) reported the mean values for open well, tube well, and boreholes in the following ranges 5.4-12.2, 4.1-24.0, and 8.5- 10.9 in Fadama lands of Southwestern Sokoto Rima Basin.

Lone *et. Al*., (2003) recorded the bicarbonate content of sewage water and tube well water from Hassanabdal area district Attock was 12.10 meq/L and 2.6 meq/L respectively. Minakshi *et. Al.,* (2006) recorded the bicarbonate content of ground water samples in Rupnagar District in Punjab (India) ranged from 1.0 to 8.0 me/L. Acharya *et. al*., (2008) noted the bicarbonate content of bore well water samples of Bhiloda taluka region North Gujarat ranged from 2.90 to 15.00 meq/L. The highest concentration of 15.00 meq/L was recorded in Jayla village and lowest value of 2.90 meq/L was observed in the water sample.

1.7.8 CARBONATE

Graham, et al., (2006) reported the mean carbonate values for open well, 0.00-6.0, for tube well, 2.0-0.5 and for boreholes 0.0-3.5 in fadama lands of Southwestern Sokoto Rima Basin

Lone *et. al*., (2003) recorded the carbonate content of sewage water and tube well water from Hassanabdal area district Attock was 2.5 meq/L and 0.46 meq/L respectively.

Minakshi *et. al.,* (2006) recorded the carbonate content of ground water samples in Rupnagar District in Punjab (India) ranged from 2.0 to 4.0 me/L.

Acharya *et. al*., (2008) noted the carbonate content of bore well water samples of Bhiloda taluka region North Gujarat ranged from 0.6 to 1.6 meq/L. The highest concentration of 1.6 meq/L was recorded in Bhatea village and lowest value of 0.6 meq/L was observed in the water sample from Jinava.

b) CHEMICAL CHARACTERISTICS OF TUBE WELL WATER

1.7.9 TOTAL HARDNESS

Singh, (2000) recorded the total hardness of 0.32 for the tube well water in Zamfara state Danko, (1997) obtained the total hardness ranged from 0.24 to 0.38 inside the reservoir and at the bank of Goronyo reservoir in Sokoto state. Hardness is generally high in ground waters in relation to surface waters. The moderate hardness of surface waters may also be due to the addition of sewage directly into the canal. Lone *et. Al.,* (2003) noted the total hardness of ground water for residential and industrial of Sanganer area Jaipur in Rajasthan varying from 68 to 515 mg/L and 88 to 1602 mg/L respectively. The alkalinity of ground water from residential area was higher than desirable limit and for industrial area its value was too high. . Unnisa and Khalilullan (2004) recorded mean values of total hardness of ground and surface water of Kattedan industries area was 2182 mg/L and 1363 mg/L respectively. All the ground and surface water samples could be included under very hard category. The lower values in surface water when compared with ground water can be attributed to dilution of ionic constituents. Hussain *et. al*., (2008) recorded the total hardness of river water in Shatt-Al-Hilla city ranged from 340 to 1060 mg/L. Acharya *et. al*., (2008) noted the total hardness of bore well water samples of Bhiloda Taluka region North Gujarat ranged from 3.1 to 12.3 meq/L. The lowest value was recorded from Sunokh and the highest value from Kebava. The values of total harden of

77% samples are within the permissible range i.e. 30 mg/L (ICMR 975). The total hardness ranged from 45 to 320 mg/L of underground water in V.V. Nagar and near by places of Anand district, Gujarat (Mishra *et. al*., 2008). . Chawala *et. al*., (2001) noted the chloride content in village pond in Ludhiana district (Punjab) with respect to irrigation and was found in range 1.4 to 8 mg/L. Sharma *et. al*., (2002) recorded the chloride content in river Namada, tap water, hand pump water and pond water at Jabalpur and the average values were 13.7, 11.9, 11.9 and 81.3 mg/L respectively. Lone *et. al*., (2003) recorded the chloride content of sewage water and tube well water from Hassanabdal area district Attock was 1.53 meq/L and 0.21 meq/L respectively.

Lone, *et. al*., (2003) noted the chloride content varying from 24 to 1050 mg/L of ground water of Sanganer area Jaipur in Rajasthan. The value was within the prescribed limit. Unnisa and Khalilullan (2004) recorded mean values of chloride of ground and surface water of Kattedan industries area was 2085.2 mg/L and 613.6 mg/L respectively. The results of surface and ground water for presence of chloride have shown a higher concentration comparing with the standards. In surface water the high concentration of chloride will be due to sewage and many of soluble salts found in soil. Khadkar and Dixit (2004) recorded the chloride content of Ambanala river water in Amaravati was 145.2 mg/L which was within the permissible limit for irrigation (142 to 355 mg/L). Nair *et. al*., (2005) noted the average value of chloride from ground water of NE Libya was 420 ppm. The presence of chloride in large amounts may be de to natural processes such as the passage of water through natural salt formations in the earth or it may be an indication of pollution from sea water or industrial or domestic use. Minakshi *et. al*.,

(2006) recorded the chloride content of ground water samples of Rupnagar district of Punjab varied from 3 to 9 meq/L.

CHAPTER TWO

STUDY AREA

2.1 LOCATION

Sokoto Rima Basin is located in north-western Nigeria and is enclosed in a roughly rectangular area bounded by Kamba (3^0 45^1 E) in the West, Faskari (6^0 13^1 E) in the East, Illela (13^0 55^1N) in the North and Yelwa (10^0 49^1 N) in the South.

Udo (1970), furnishes that administratively, the region consists of the two most senior emirates of Sokoto and Gwandu.

The area is thus coterminous with colonial Sokoto province (1903 – 1967) which was later designated the North Western state in 1967 and subsequently partitioned Sokoto and Niger state in 1967. The Sokoto Rima Basin covers the Kebbi state, (created in 1991 from the 1976 Sokoto state), Zamfara state (created in 1996) and the present Sokoto state which emerged after the two states creation exercises. The Northern section of Niger state and the South Western portion of Katsina state, however, are also part of this basin according to its technical demarcation. Udo (1970) estimates that, while the Sokoto Basin covers some 93,240 km, that of Rima occupies 90,650km^2. Thus the total is 82,883 km^2 but Swindell (1982) demonstrate that the Sokoto-Rima Basin officially occupies an area of 101,007 km^2, this implies that land mass of 18,124 km^2 is contributed by some sub-basins in Katsina and Niger states.

2.2 CLIMATE

The Sokoto-Rima basin has a semi-arid tropical climate with a prolonged dry season from October-May and a short wet season from end of May to early October (Udo, 1970; Ogheneakpobo, 1988; Adeniyi, 1993). The northern part of the study area is drier while

the south is wetter (Gill, 1974). The area has uniformly high temperatures throughout the year (Udo, 1970; Gill, 1974). Temperatures depict both seasonal and diurnal variations in the area (Davis, 1982 c). Two temperature maxima of over 35°C are common between April-May and between October-November (Gill, 1974; Adeniyi, 1993). Two minimum temperature periods below 20°C are also common between December-January and in August (Gill, 1974; Adeniyi 1993). The lowest temperature of the area is about 13°C between December and January (Bello, 2002). During the rainy season, the diurnal range of temperature in the- area is low but during the dry season it is high (Davis, 1982 c). ;

Rainfall in the area shows both spatial and temporal variations (Udo, 1970; Adeniyi, 1993). The mean annual rainfall varies from about 700mm in the northern part of the Rima basin to about 1,100mm in the south (Gill, 1974; Davis, 1982 c; Adeniyi, 1993). The duration of the rainy season is also longer in the southern part (Davis, 1982 c) since it begins earlier and ends later than in the north (Gill, 1974).

2.3 GEOLOGY AND RELIEF

The study area is part of the Sokoto-Rima basin. The basin can be divided into two major geological regions (Udo, 1970; Gill, 1974; Davis, 1982 b). The geological regions are the pre-Cambrian Basement complex rocks in the south-east of the basin and the sedimentary rocks of the lullemmeden basin in the north-west (Udo, 1970; Gill, 1974; Davis, 1982 b).

The immediate study area is precisely underlain by sedimentary rocks (Ogheneakpobo, 1988). There are two major sedimentary rock categories[1] related to the study area (Udo, 1970). The first category comprises of the Rima Group of sediments (Taloka formation, Dukamaje formation and Wurno formation) and the Cretaceous sediments of Illo-Gundumi formations (Udo, 1970; Davis, 1982 b). The; Taloka and Wurno formations are

identical and they consist of sandstones, mudstones and siltstones (Davis. 1982). The Dukamaje formation consists of shales, limestones and mudstones (Davis, 1982 b). The Illo formation consists of pebbly grits, sandstones and clays while the Gwandu formation consists of clayey grits, clays, sandstones and conglomerates (Davis, 1982 b).

The second category of sedimentary rocks comprises of the Tertiary sediments of the Palaeocene Sokoto Group (Dange formation, Kalambaina formation and Gamba formation) and the Eocene Gwandu formation (Udo, 1970; Davis, 1982 b). The Dange formation consists of shales interbedded with limestones and phosphate concretions as well as conglomerates (Davis, 1982 b). The Kalambaina formation consists of shales, limestones and mudstones (Davis, 1982 b). The Gamba formation consists of shales overlain by sand and laterite (Davis, 1982 b). The Gwandu formation consists of clays, clayey grits, mudstones and sandstones (Davis, 1982 b).

The Sokoto-Rima basin is generally □hysic□riate□ by flat and gently rolling landscape which is interrupted by inselbergs, ridges and rock outcrops in some areas (Gill, 1974; Adeniyi, 1993). The area can be broadly grouped into three: the uplands or High Plains, the Sokoto Plains, and the flood plains or riverine lowlands (Gill, 1974; Davis, 1982 a; Adeniyi, 1993). The High Plains or uplands are in the southeast and they consist of highly dissected Basement Complex rocks with relief of about 600 – 700m above sea level (Gill, 1974; Davis, 1982 a; Adeniyi, 1993). The Sokoto Plains are at the north and centre of the basin and they have the highest areal coverage in addition to being monotonous lowland which has a relief of about 300 – 450m above sea level on the sedimentary rocks (Gill, 1974; Davis, 1982 a; Adeniyi, 1993). The monotony of the Sokoto Plains is interrupted by laterite-capped, tabular hills called mesas (Davis, 1982a;

Adeniyi, 1993). The flood plains or *fadamas* are a coniplex of stream channels which form lowlands with lowest relief of usually less than 300 m above sea level (Gill, 1974; Davis, 1982 a; Adeniyi, 1993).

2.4 DRAINAGE AND HYDROLOGY

The drainage system of the area is dominated by the! Rima river and its tributaries (Davis, 1982 d). The main tributaries include the rivers Bunsuru, Gagare, Maradi, Sokoto, Gawon Gulbi, Zamfara and Gulbin Ka (Gill 1974; Davis, 1982 d). The river Gawon Gulbi contributes little flow to the Rima drainage system (Gill, 1974; Davis, 1982 d) while river Maradi seldom contributes (Gill, 1974). The drainage pattern is dendritic and the lower order streams flow in all direction (Davis, 1982 d).

The Rima river and its tributaries form broad flood plains or *fadamas* on the sedimentary rocks (Davis, 1982 d). The *fadamas* are important because of their hydrological influence and agricultural potentials (Davis, 1982 d). *The fadamas* have storage capacity that facilitates attenuation of flood waves (Gill, 1974). This helps in moderation of river flow and in reducing flood peaks (Gill 1974; Davis, 1982 d).

Stream flow is influenced by surface water runoff and ground water discharge (Gill, 1974; Davis, 1982 d). This implies that the stream flow is controlled by basin characteristics (such as size, shape and relief) and by precipitation characteristics such as distribution, seasonality, duration and intensity (Gill,; 1974; Davis, 1982 d). Stream flow is more concentrated in the rainy season and especially between August to September when floods are common (Gill, 1974; Davis, 1983 d). Most of the rivers become dry during the dry season with the exception of few perennial rivers such as the Rima, Sokoto and Zamfara (Gill, 1974; Davis, 1982 d).

Ground water storage exists in sedimentary rocks under water table and artesian (pressure) conditions (Gill, 1974; Davis, 1982 d). The ground water is more common in Gwandu formation and Kalambaina formation (Gill, 1974; Davis, 1982 d). The sedimentary rocks also yield some base flow to some of the rivers as in the case of the Gwandu formation which supplies water to river Zamfara through ground water inflow (Gill, 1974; Davis 1982 d).

2.5 SOILS

The study area has mostly sandy soils which have low organic matter and nutrients – nitrogen, phosphorus, and potassium (Swindell, 1986; Yelwa and Eniolorunda, 2012). The- sandy soils are associated with uplands or *tudu* and they may be ferruginous soils or ferralitic (kaolinitic) soils (FAO, 1969; Udo, 1970; Swindell, 1986). These soils are light, porous, and have low clay content and low cation exchange capacities (FAO, 1969; Swindell, 1986). Such soils also have sandy A horizons and clayey B horizons in their profiles (Udo, 1970). Concretions of laterite and duricrust may occur in the B horizons of the sandy soils which make the soils toibe uncultivable (Udo, 1970; Swindell, 1986). The sandy soils are associated with the following sedimentary formations: Gundumi, Illo, Gwaiidu, Taloka, Dukamaje and Wurno (FAO, 1969).

The flood plain *or fadama* soils are in contrast to the upland sandy soils (Udo, 1970; Swindell, 1986). *The fadama* soils are mostly hydromorphic soils which are clayey and loamy with grey or black colour (Swindell, 1986). They are also highly fertile due to high nutrient contents and high cation exchange capacities (FAO, 1969; Udo, 1970; Swindell, 1986). The hydromorphic soils occur in riverine areas and are annually renewed by floods and associated silt deposition (Swindell, 1986).

2.6 VEGETATION

The vegetation is the sudan savanna type with short grasses and trees (Udo, 1970; Davis, 1982 e). The sudan savanna is influenced by many physical and human factors (Davis, 1982 e). Changes in vegetation composition take place in a north-south direction so that the northern part has a low plant density while the southern part has higher density (Davis, 1982

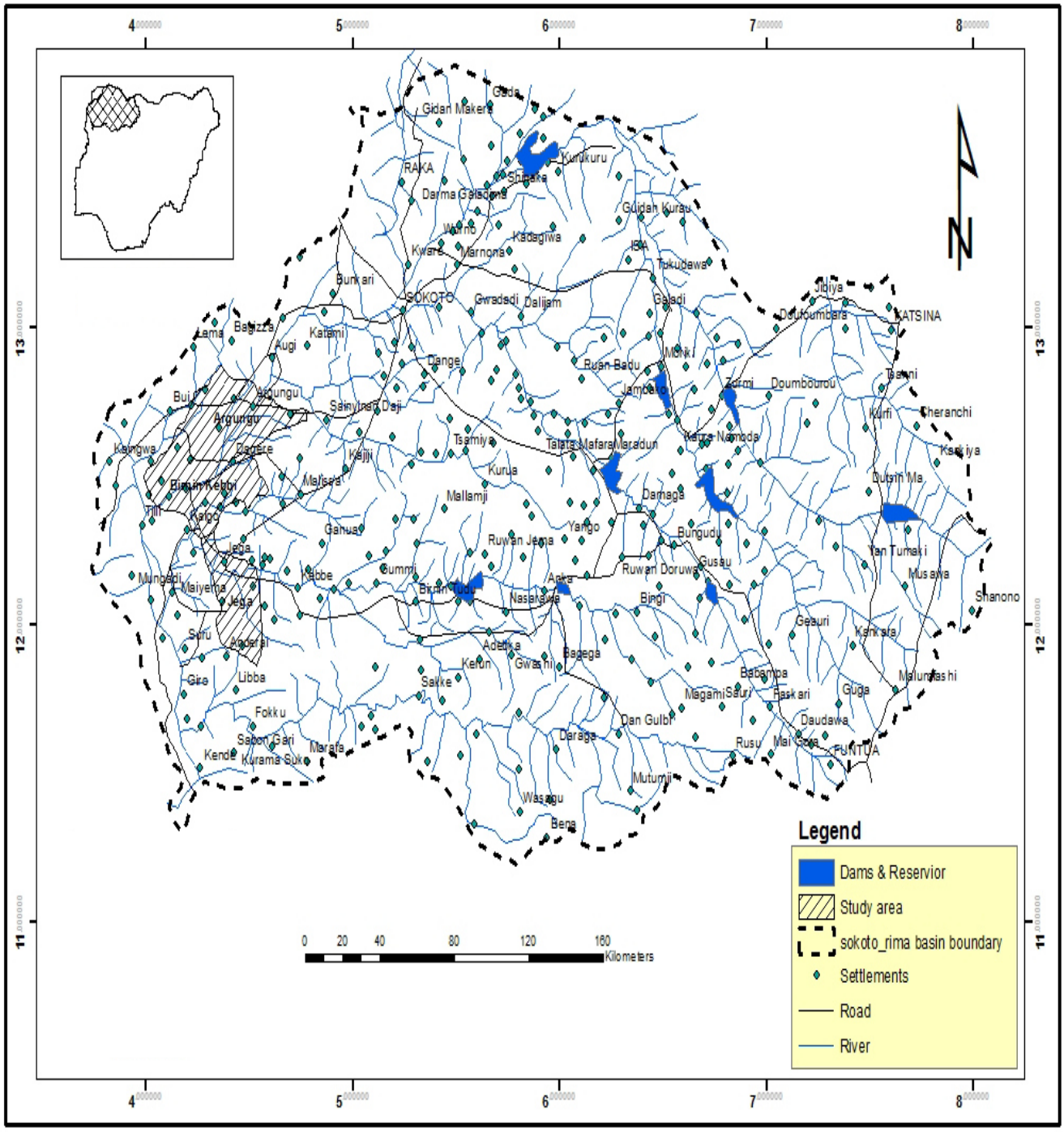
The vegetation of the study area has been grouped into; seven categories (FAO, 1969; Davis, 1982 e). The categories are woodland, savanna woodland, tree savanna, shrub savanna, farmed parkland, riverine woodland, and semi-aquatic non-tree vegetation (FAO, 1969; Davis, 1982 e). The woodland has a closed canopy of medium-sized trees about 10m to 15m in height (Davis, 1982 e). The savanna woodland has open stands of medium sized trees 8m to 10m in height with a closed canopy under which small trees and shrubs grow while in the absence of the canopy grasses grow (Davis, 1982 e). The tree savanna has open units of vegetation with low shrubs or grasses and medium-sized trees which may occur singly or in clusters (Davis, 1982 e). The shrub savanna has only shrubs with the absence of trees (Davis, 1982 e). The farmed parkland is a farmed land with scattered trees (Davis, 1982 e). The riverine woodland is a complex plant formation which has many categories of vegetation including riparian forest, woodland, tree savanna and shrub savanna (Davis, 1982 e). The semi-aquatic non-tree vegetation has grasses, herbs and shrubs which are regularly flooded but not permanently waterlogged (Davis, 1982 e).

The most common trees in the study area include *Acacia albida (gawo),* shea butter *(Butyrospermum parkii),* the dum palm *(Hyphaene thebaica),* the baobab *(Adansonia*

digitata), neem tree *(Azadirachta indicd),* locust bean! *(Parkia clappertonia),* kapok *(Bomba costatum), Combretum nigricans, Isoberlina 'doka,* and *Tamarindus indica* (FAO, 1969; Udo, 1970; Davis, 1982 e). The most common shrubs in the area include *Combretum spp., Piliostigma spp.* And *Terminalia spp.* (FAO, 1969). The most common grasses include *Loudetia togoensis, Andrdpogon spp.* And *Pennisetum pedicellatum* (FAO, 1969). \

2.7 LAND USE IN SOKOYO RIMA BASIN

Udo (1971) describe subsistence farming practiced by traditional methods and animal husbandry as the two dominant land use patterns in the Sokoto Rima Basin. Farming however remains by far the most important source of livelihood. Farming in the area is dominated by a grains economy based on the cultivation of Millets, Guinea-corn, Maize, Beans and Vegetables for food but Cotton, Tobacco, Groundnuts and some specific crops (Peppers, Tomato, Onions, Sugar cane, swamp Rice and Wheat) for cash (Udo, 1970). Davis, (1982) however add that Pastoralism, artisanal fishing, hunting and gathering are also predominant livelihoods. Uniquely, land use in the basin is specialized on ethnic lines; Hausa cultivate crops while the Fulani specialized in pastoralism. Davis, (1982) outlines that the several minority ethnic groups (Arawa, Gungawa, Jemani, Kambari, Kabawa, Larawa, and Lopawa) who live along the riverine areas, engages mainly in fishing as their main means of livelihood.



Source: UNDP/FAO, Soil and Water Resources Survey of the Sokoto Valley, 1969. Reproduced @ the Dept. of Geog BUK (2015)

Fegure 2.2 Map of the Study area (Sokoto Rima Basin)

CHAPTER THREE

RESEARCH METHODS

3.1 RESEARCH DESIGN

It involves listing the essential considerations to be followed in the research undertaking. It is in other words a general arrangement and planning of the manner in which the research is to be conducted. It deals with materials and methods, listed of specialized materials and detailed description of the method employed as well as laboratory analysis, It also described sampling frame, sampling size and technique source of data, fieldwork, collection and laboratory analysis of water samples, data presentation and statistical techniques

3.2 PRE FIELD INVESTIGATION

A reconnaissance survey was conducted. It was conducted to make the study area more familiar and accessible for the main field survey. The reconnaissance helped fine-tuning the strategies adopted before the field investigation.

3.3 SAMPLING FRAME, SAMPLE SIZE AND SAMPLING TECHNIQUE.

Kebbi Agricultural and Rural Development Authority (KARDA) has conveniently divided the state into four zones (i. Argungu ii. Bunza iii. Zuru iv. Yauri). Each zone has a number of Fadama Users Associations (FUA) under National Fadama Development Project (NFDP). Zone 1which is Argungu is the area of my study. The zone has sixty five (65) Fadama Users Associations which form the sample frame for this study. Sample will be drawn from the sample frame. Considering the size of the sample frame which is 65, thirty percent of sample frame will be taken as the sample size. Thirty percent of 65 is

approximately twenty. Therefore the sample size is twenty fadama users association from the study area.

For this study 20 Fadama users association were randomly choosen they were, Huda, Mangoron Jega, Unguwar Dannana, Gulumbe, Alwasa, Bayawa Getare, Illelar Galbi, Kimba, Zauro Kiyaki, Kurmi, Kardi, Matan Fada, Basaura, Bubuche, Dangamayi, Farfajiya, Tiggir Galbi and Asarara.

3.4 FIELD WORK PREPARATION

This involves site visit to collect water samples from selected stations in the study area. Containers (a clean 2- litre plastic container provided with cap) of the water samples were marked with figure 1- 20 respectively. The figures correspond with the (FUAS) in the list.

3.5 COLLECTION OF WATER SAMPLES

In order to conduct analysis of a particular irrigation water, a representative sample is needed. Sampling means to take a part that is essentially a true representative of the material being sampled. Water samples were collected from 20 different areas across the flood plains of continuous cropping through irrigation agriculture.

3.6 PROCEDURE FOR SAMPLE COLLECTION

Water samples were collected for the determination of physical and chemical parameters. Containers (a clean 2- litre plastic bottles) were used to collect water samples from randomly chosen (FUAS). The tube well water were pumped out for 20 minutes before the collection of samples. This was done to enable the collected samples be a true

representative of the water from the aquifer. Random sampling table of numbers was used in choosing the sampling points.

3.7 EXPERIMENTAL DETAILS

Titrimetric (See details in appendix)

3.7 DATA PRESENTATION AND ANALYSIS

Data obtained from laboratory analysis was presented by using tables.

The data generated is tabulated and statistically analysed using mean and descriptive statistical technique.

A bivariate correlation analysis produces Pearson's correlation coefficient I. the correlation coefficient gives a mathematical value for measuring the strength and magnitude of the linear relationship between two bivariates. The value of relationship takes value ranging from -1 to -1, where +1 representing an absolute perfect positive linear relationship (as x increase, y increase). Zero representing no linear relationship between the bivariates (x and y have no pattern), whereas -1 represents an absolute inverse relationship between bivariates (as x increases, y decreases). The sign in front of the correlation coefficient determines the direction of the relationship. A plus sign denotes positive relationship and a minus sign denotes positive relationship and a minus sign denotes negative correlation.

Principal component analysis and factor analysis.(PCA/FA)

PCA/FA are statistical approaches that can be used to analyze interrelationships among a large number of variables and to explain these variables in terms of their common underlying dimension by providing empirical estimates of the structure of variables (Singh et al, 2004). The objective of PCA/FA is to reduce the number of variables

necessary to describe the observed variation within a datasets. PCA/FA lessens the number of variables understudy and discovers the structure between the variables (Pejman *et al,* 2009). This is achieved by forming linear combinations of the variables (components) that describe the distribution of the data (Mustapha and Aris 2012). The linear combinations are derived from some measures of association such as correlation or covariance matrix. PCA converts the original dataset which comprises of measurements for each variable measured for each sample and converts them to an equal number of composite variables (Mustapha and Nabegu 2011; Mustapha et al, 2012).

In order to maximize the relationship between the variables under study, the factors are rotated. Factors rotation is used to facilitate interpretation by providing a simpler factor structure (Sevilla *et al,* 2010). Factor rotation has been used to extract related variables and infer the processes that control surface water chemistry. Varimax rotation is applied to the PCs in order to determine factors that can be easily explained (Shrestha and Kazama 2007). The goal of rotation is to maximize the variance (variability) of the new variable while minimizing the variance around the new variables (Tiri and Boudoukha 2010). The relevant information is carried out by the first principal component (PCs). PCs are ordered in such a way that the variance of the first PCs (PC1) is the highest, the variance of the second PCs (PC2) is the second highest, and so on, whereas the last PCs is the lowest in explaining variation of the data sets (Chabukdhara and Nema 2012). PCA can be expressed using the equation below:

$$yji=filzil+fj2zi2+\ldots\ldots\ldots+fjm+zim+eij$$

Where y is the measured variable, f is the factor loading, z is the factor score; e is the residual term accounting for errors or other sources of variation, I and j is the sample number and m is the total number of factors.

The F statistics calculate the ratio between the variance due to difference between group and error variance. The larger the F ratio, the greater is the difference between groups as compared to within-group differences.

The total sum of square (TSS) is based upon the sum of the square deviations between the observations in the table and the overall mean. The between sum of square (BSS) is based upon the square deviations between column means and the overall means, and the within sum of square (WSS) is based upon the squared deviations between the observation and the column means. The F statistics is constructed by dividing each sum of squares by its degree of freedom as in equation below:

$$\text{F statistics} = \frac{BSS/(k-1)}{WSS/(n-1)}$$

An F ratio equal to or less than 1 indicates that there is no significant different between the groups and the null hypothesis is correct. However, if the F test proves the null hypothesis to be wrong, multiple comparison tests are used to further explore the specific relationships among different groups.

CHAPTER FOUR

PRESENTATION AND DISCUSSION OF THE RESULT

4.1 INTRODUCTION

This chapter presents result and discussion of the study and the data obtained from the Chemical Laboratory analysis as presented in tables. The range and mean of some physical and chemical characteristics of the sampled tube well water under irrigation is presented. Pearson product moment correlation analysis of physicho-chemicals parameters was used to examine the relationship of the variables, further principal component analysis with Varimax and Kaiser normalization were used to identify the principal sources of pollution in the tube well water, moreover hierarchical clusters analysis was conducted on the data set to group the tube wells based on characteristics they possesses.

4.2 DESCRIPTION AND STANDARD GUIDELINES FOR DRINKING WATER, IRRIGATION AGRICULTURE AND DOMESTIC USES

4.2.1 pH

Table 1. Shows that the pH range for tube well water in Fadama land of Southwestern Rima Basin of Kebbi State was 5.0 – 6.6 (Mean 6.3). this is comparable to the mean pH of 6.7 for the West African groundwater given by Roose and Leong (1981). This pH range 5.0 – 6.6 is within 6.5-8.8 given by Du Preiz (1961) for the underground water in Nigeria basement complex. The values are almost similar to pH 5.1-7.8 (Mean 6.7) for tube well water in Zamfara State (Singh 2000). Singh (2000) gave the values of 3.3-8.4 (Mean 7.5) for tube well water in Kebbi State. However the obtained means of 6.3 was

below the mean pH value of 7.3 for water from 6.3 was below the mean pH value of 7.3 for water from Rivers and stream in Sokoto State (Singh and Tsoho 2000). Mustapha et al (2011) gave pH values range from 5.6 – 10.6 (mean 7.9) for surface water of River Jakara Kano State. As a matter of fact, the mean value were within the pH range 6.5-8.4 which is considered the normal range for irrigation waters according to Ayer and Westcott (1976) as well as FAO (1985). The reported range 5.0-6.6 (mean 6.3) agrees with observation of Singh et al (1996) and Singh and Tsoho (2000) that water from Kandoli Shela stream. Rima River and Goronyo Dam in the Fadama Area of Sokoto State was neutral to slightly Alkaline in reaction.

However, on the individual basis1 of the total samples (5%) were within the normal range of 6.5 – 7.7, that is slightly acidic to slightly alkaline, while 11 out of the total samples (55%) fell within the range of 6.0 – 6.4 and lastly 8 out of the total samples (40%) were within the range of 5.0 -5.9 which is considered acidic. Thus 8 samples (40%) of tube well water samples may be associated with extreme pH condition while majority of the samples that is 12 (60%) appears free from problems associated with pH condition. It can therefore, be safely used for irrigation.

4.2.2 ELECTRICAL CONDUCTIVITY (EC)

Electrical Conductivity measures the ability of the water to conduct an electrical current and depend upon the number of irons or change particles in the water (Dan Azumi and Bichi 2011). The EC range was 0.4 – 1.17 with mean value of 0.32μScm^{-1} which shows that there is no salinity hazard in the study area as of the time the sample were collected, this is because the mean value of EC is below the maximum permissible limit by NSDW, WHO and AWWA set guidelines for various uses. The mean value of EC 0.32μScm^{-1} is

comparable to the mean value 0.31µScm^{-1} for the surface water of Jakara River given by Mustapha et al (2011) Singh (2000b) gave EC value 49-16 832 µScm^{-1} (Mean 417) for tube well water in Kebbi State. However, the obtained mean value of 0.32 was below the mean EC of 417 µScm^{-1} Danko (1997) gave the mean values for Goronyo Dam, Wurno 1 project and Kwalkwalawa as 0.80, 0.120 and 0.220 respectively are lower than the mean value of EC 0.32 in this study.

4.2.3 DISSOLVE OXYGEN (DO)

Dissolve Oxygen is one of the most important parameter in determining the quality of water and the effect of oxidation waste on streams(HACH company 2008) and it is influenced by the sources of the water, temperature, treatment, chemical and biological process taking place in the distribution system (WHO 2004).

Table 1 show that the DO range for tube well water in South Western Rima Basin to be 4.5mg/l – 6.7mg/l (mean 5.7). the mean value DO of 5.7mg/l, it is very closed to the mean value of 4.34mgl^{-1} obtained by Mustapha et al (2011) it shows that DO concentration value is within the NSDW and WHO guidelines and also it is recommended for irrigation agriculture and domestic uses by AWWA. Abduljameel (2002) gave DO of 2.0mg/l – 4.2 mg/l for water of Tiruchirapalli, Tamilnadu which varied from DO content of ground and surface water of Gostani and Velpur canal of Tanuku Town ranged from 4.50 mg/l – 5.24 mg/l and 4.25 mg/l – 6.42 mg/l (Srinivas *et al.,* 2002).

4.2.4 BIOCHEMICAL OXYGEN DEMAND (BOD)

BOD has long been used to determine the level of organic pollution in water and it is part of organic matter which undergoes biotic decomposition.

Table 1 shows the (BOD) range for tube well water of Fadama areas of South Western Rima Basin which is 18.6 – 25.7 (mean 22.53). The mean value of BOD obtained by Mustapha et al (2011) was 4.08 mg/l for surface water of Jakara River.

4.2.5 CARBONATE (CO_3) AND BICARBONATE (HCO_3)

The range for carbonate CO_3 and HCO_3 were 0-0 (Mean 0) and 1.7 – 2.3 (Mean 2.0) Mg/l respectively (table 1) the values are almost similar to CO_3 and HCO_3 0-5mg/l (mean 2) and 1-34 (mean 17) Mg/L for tube well water in Zamfara State (Singh 2000) in terms of the residual Sodium Carbonate (RSC). The tube well in the Fadama land of South Western Rima Basin (Kebbi) was discovered to have negative RSC (Table 1). This indicate the presence of negligible amounts of carbonate and bicarbonate.

Based on the report by Wilcox (1954), that water with RSC < 1.25 mg/l is safe for irrigation, the tube well water of the Fadama land of South Western Rima Basin (Kebbi State) could be safely used for irrigation in term of Carbonate and bicarbonate hazards.

DU Preez (1961) reported no carbonate in the Nigeria basement complex. Singh (2000a) believed that water from both Kebbi and Zamfara States had negative RSC Indicating the presence of negligible amount of carbonate and bicarbonate. However,, Singh and Tsoho (2000) opined that the surface water in Sokoto except that from Goronyo Dam, had some amount of RSC, though the values were quite low within the range 0.01-0.28 mg/l.

4.2.6 CONCENTRATION OF BASIC CATIONS

The overall ranges (mean) for Ca^{++}, Mg^{++}, K^{+} and Na^{+} respectively were 0.7 – 3.3 (1.86), 1.40 – 2.95 (2.13), 0.5-9.8 (2.64) 0.5-5.8 (1.99) mg/l) Table 1). The values for Ca were lower than 1.8 -12.0 mg/l reported by Roose and Lelong (1981) for West African ground water and 57 mg/l reported by Singh et al (1996) for Kandoli Shela stream water in Sokoto State. Singh (2000) reported the value for Ca^{++} in Kebbi State as 29-467 (mean 117) mg/l while for Zamfara state underground water Singh (2000) reported the Ca^{++} values as 66-298 (mean 195) mg/l. the obtained value was also lower than 9.98-57.89 mg/l as reported by Hunting Technical Service Limited (1970) for water along the Falloi Maouri Valley in the Niger Republic.

However, the obtained values for Mg were similar with 0.4-10.0 Mg/l reported by Roose and Lelong (1981) for West African Ground Water and Lower than 18-898 (mean 179) Mg/l for Tube Well in Kebbi State (Singh 2000). The Mg values were also lower than 18-300 (mean 159) Mg/l for Tube Well Water in Zamfara State (2000). The values were also lower than 24.67-74.01 Mg/l for water along the Dallon Maouri Valley reported by the Hunting Technical Services Limited (1970) in Niger Republic.

The obtained values for K^{+} and Na^{+} were higher than the minimum value and lower than the maximum values 0.3-19.0 and 0.2 -49.0 Mg/l, respectively as reported Roose and Leong (1981) for the West African ground water. The values were also lower than 3-420 (mean 61) and 1-160 (mean 12) Mg/l respectively for tube well water in Kebbi State (Singh, 2000a), Singh (2000b) report K^{+} and Na^{+} values for Zamfara ground water as 1-19 (mean 6) and 3-19 (mean 13) Mg/l respectively. Singh et al (1996) reported 9 and 2 Mg/l values for K^{+} and Na^{+} respectively for Kandoli Shela stream water. Hunting

Technical Service Limited (1970) obtained values of 13.43-24.30k and 0.07-74.21 Na Mg/l for water along the Dallon Maouri Valley in the Niger Republic.

Calcium Salts are known to cause salinity problem. Fortunately enough, its concentration in the Tube Well *Water within the Fadama land* of South Western Rima Basin (Kebbi State) is quite low. Greatly lower than some of the basic cations. Its concentration in the water, therefore is not of much concern atleast at this material time.

Substantially high concentration of Mg^{++} and K^{+} in irrigation water suggests that it contains a lot of Mg^{++} and K^{+} Salts. Continuous and particularly excessive irrigation with such water may lead to build-up of salts and subsequent Salinazation. Sodium on the other hand leads to soil sodication. Fortunately, its concentration in almost all the tube well water was quite low.

Table 4.1– Mean SD and Range of physical chemical parameter in the study area.

Parameters	Mean	SD	Minimum	Maximum	NSDW 2007 Maximum permitted for drinking water	WHO (2004) Highest permitted for drinking water	AWWA(1999) Maximum permitted for drinking water
pH	6.325	26.87	5.0	6.6	6.5-8.5	6.5-8.5	6.5-9.2
EC (µs/cm)	0.319	6.05	0.04	1.17	1000	1500	200
DO (mgL^{-1}	5.655	24.02	4.5	6.7	5-7	5	5
BOD_5 (mgL^1)	22.53	95.71	18.6	25.7	5-7	5-7	5-7
CO_3 (mgL^1)		- - - -					
HCO_3 (mgL^1)	2.01	8.353	1.7	2.3			
CL (mgL^1)	1.1	4.67	0.7	3.4			
NO_3 (mgL^1)	0.62	2.63	0.2	1.4	5	5	500
PO_4 (mgL^1)	0.23	0.97	0.20	0.25	100	5	100
Na (mgL^1)	1.985	8.43	0.5	5.8	200	200	A
K (mgL^1)	2.635	11.19	0.5	9.8	200	200	A
Ca (mgL^1)	1.835	7.92	0.7		200	200	A
Mg (mgL^1)	2.13	9.06	1.40	2.95	250	200	A
TDS(mgL^1)	1.45	6.15	1.0	4.0			
SS (mgL^1)	0.35	1.48	1.0	2.0			

Source: Field Survey 2014.

4.3 RELATIONSHIP BETWEEN PHYSICOCHEMICAL PARAMETERS UNDER STUDTY

Table 2 Presents the result of bivariate correlation coefficients for tube well water in Fadama land of Southern Rima Basin. The relationship of 20 parameters under study was investigated using pearsons' product moment correlation.

As depicted in the table (2) analysis of correlation coefficients shows. Significant linear relationship for variables describing the oxygen conditions of water and organic compound. The value of correlation coefficient equal 0.977 for DO and BOD_5. It also shows significant linear relationship for variables describing the concentration of basic cations. The values of correlation coefficient equals 0.943 for the pair of EC and Na, 0.696 for the pair of EC and K, 0.660 for the pair of EC and Ca, 0.508 for the pair of Mg, 0.587 for the pair Na and Ka, 0.641 for the pair of Na and Ca, 0.615 for the pair of Na and Mg and finally 0.462 for the pair of Cl and K.

BOD_5, $P0_4$ and $N0_3$ had long been the basic means of determining the degree of organic pollution in surface water (Mustapha et all 2013). DO is one of the most important parameter in determining the quality of water and the effect of oxidation waste on streams (HACH Company 2008 and Mustapha (2011). The DO with BOD correlation can be explained by the fact that BOD_5, represented liable organic matter which undergoes biotic decomposition and is part of DO. The value of correlation coefficient shows significant linear relationship between DO and BOD (0.977) the correlation can be explained by the organic compound used for domestic activities in the vicinity of the study areas. This finding seems to be consistent with other research which found that urban land type with the effect of increased population, domestic water use were possibly

associated with increase in water quality variations(Singh et al, 2004, Mustapha et al (2012).

The strong relationship can be attributed to the natural source of pollution; than can be achieved through silicate weathering of rock which will release, cations and anions in the water. Silicate weathering is the major sources of cations. It can also originate from anthropogenic (human) sources from fertilizer, road salt, human and animal waste and industrial application. Many of these mineral can be carried in solution, the type and concentration which depends upon several factor like soluble product of rock weathering and decomposition in addition to external polluting agencies and changes in space and time. It can be as a result of chemical and biochemical interaction between ground water and contaminant from carbon industrial and Agricultural activities along with the geological minerals through which it flows, it contain a wide range of dissolved on organic chemical constituents in various concentration.

However, the resulting correlation analysis shows the presence of two auto-correlation viz- a. correlation between DO and BOD (.977), -b Na and EC to the value of .943. Meanwhile in either of the two cases the presence one parameter can stand inplace of the other.

Table 4. 2. Zero- order correlation matrix of physicochemical parameters under study

	PH	EC	DO	BOD_5	HCO_3	Cl	NO_3	PO_4	Na	K	Ca	Mg	TDS	SS
PH	1													
EC	-0.262	1												
DO	0.083	0.179	1											
BOD_5	0.113	0.190	.977**	1										
HCO_3	0.113	-0.036	0.288	0.180	1									
Cl	-0.256	0.179	0.306	0.383	-0.079	1								
NO_3	-0.021	0.078	-0.424	-0.337	-0.307	0	1							
PO_4	-0.063	-0.238	-0.274	-0.180	-0.095	0.262	0.098	1						
Na	-0.149	.943**	0.212	0.233	0.099	0.158	0.099	-0.331	1					
K	-0.382	.696**	-0.008	-0.011	-0.114	.462*	0.076	-0.192	.587**	1				
Ca	-0.345	.660**	-0.155	-0.187	0.088	0.024	-0.026	-0.029	.641**	0.387	1			
Mg	-0.061	.508*	0.097	0.120	0.017	-0.111	0.319	-0.385	.615**	0.218	0.208	1		
TDS	0.384	-0.161	-0.124	-0.068	-0.205	-0.115	0.157	0.318	-0.18	-0.211	-0.259	-0.26	1	
SS	0.219	0.055	0.012	-0.047	0.382	-0.159	-0.164	-0.115	0.125	-0.029	0.011	0.27	0.248	1

*** Correlation is significant at the 0.01 level (2-tailed).*

** Correlation is significant at the 0.05 level (2-tailed).*

4.3.2 POLLUTION SOURCES APPORTIONMENT USING PRINCIPAL COMPONENT ANALYSIS(PCA)

Principal component analysis/factor analysis was applied on the normalized data PCA was employed on the data to identifying the latent factors that influence each of the identified sources (industrial, domestic and agricultural) of pollution in Sokoto Rima Basin by cluster analysis. Five PC's were obtain with Eigen value lager than I based on the screen plot (figure 1) summing the total variability of 77.7% (Table 3) and this is considered as important ones (KowalKowski, et al 2006) and are responsible for the variance in the Sokoto Rima Basin. The results of the factor analysis are summarized in between 20 parameters under study was investigated using principle component analysis. PCA/FA assumes that the total from each element is made up of the sum of elemental concentrations from each identified polluting or natural cause component (Mustapha et al 2013, Juahir *et al.,* 2009). To obtain more reliable information about the relationship among the variable, PCA/FA was used, to explore the extent of physicochemical and source identification. Varimax rotation was used to maximized the sum of the variance of the factor coefficient which better explained the possible group/sources that influenced the water chemistry in the Sokoto Rima Basin (Singh et al 2004). The factor loading was rank following the correlation coefficient matrix between the variables.

The calculated factor loadings, accumulated variance explained by each factor in the PCA are presented in table 3.

Preliminary analysis prior to factor analysis were conducted to ensure that no violation of the assumptions of Kaiser-Meyer – Olkin (KMO) measure on the sampling adequacy and Bartlett test of sphericity. The KMO result was 0.82 and the Barlett spheroid was significant

(0.001, $P < 0.5$) showing that PCA/FA could be considered appropriate and useful to provide significant reduction in the data dimensionality (Liu, et al 2003; Mustapha et al 2012b) Five factors with eigenvalues greater than I were expected from the varimax rotated factor analysis. Factor score represent the cumulative contribution of all parameter. Loaded on a particular factor.

The first varimax component (VFI) in the Rima Basin water sets explains more than 26.8% of the total variance and is heavily loaded on Na, K, Ca. The result provides evidence of critical anthropogenic and agricultural activity impact on the study area.

VF. 2 explain 18.2% for the Rima Basin with positive strong loading on DO and BOD5. This factor can be interpreted as an anthropogenic factor of the over all measures of the sewage discharge which include pollution concentration from a domestic west charge through point source.

VF 3 Explain 13.6% and had a strong positive loading on PO_4 and Mg. this factor can be interpreted as contribution from non point pollution, especially through rainfed or irrigation agriculture. VF 4 explain 10% for the Rima Basin and had a strong positive loading factor on HCO_3 and NO_3 it indicated the domination of silicate weathering as the main sources of cations.

VF 5 in the Rima Basin water sets explains 9% with a strong positive loading on TDS and SS. The result provided evidence of ground water containing mineral carried in solution of which the types and concentration depends upon several factor like soluble products, rocks weathering and decomposition in addition to external polluting agencies and changes in space and time.

Table 4. 3. Rotated component matrices with varimax and Kaiser Normalization

	VF1	VF2	VF3	VF4	VF5
PH	-0.353	0.130	0.187	0.030	0.670
EC	0.929	0.132	0.178	-0.047	-0.021
DO	0.028	0.934	0.135	0.251	-0.004
BOD_5	0.044	0.967	0.078	0.116	0.039
HCO_3	0.020	0.084	0.116	0.796	0.084
Cl	0.335	0.512	-0.554	-0.172	-0.200
NO_3	0.136	-0.312	0.137	-0.728	0.164
PO_4	-0.097	-0.180	-0.796	-0.090	0.133
Na	0.897	0.159	0.310	0.015	0.054
K	0.771	0.074	-0.101	-0.144	-0.230
Ca	0.736	-0.305	-0.013	0.239	-0.220
Mg	0.48	0.042	0.687	-0.162	0.126
TDS	-0.129	-0.054	-0.358	-0.214	0.788
SS	0.178	-0.128	0.142	0.500	0.626
Eigen Value	3.754	2.549	1.911	1.403	1.266
Variance	26.816	18.209	13.650	10.022	9.041
Cum Var.	26.816	45.025	58.674	68.696	77.737

Source: field survey 2014

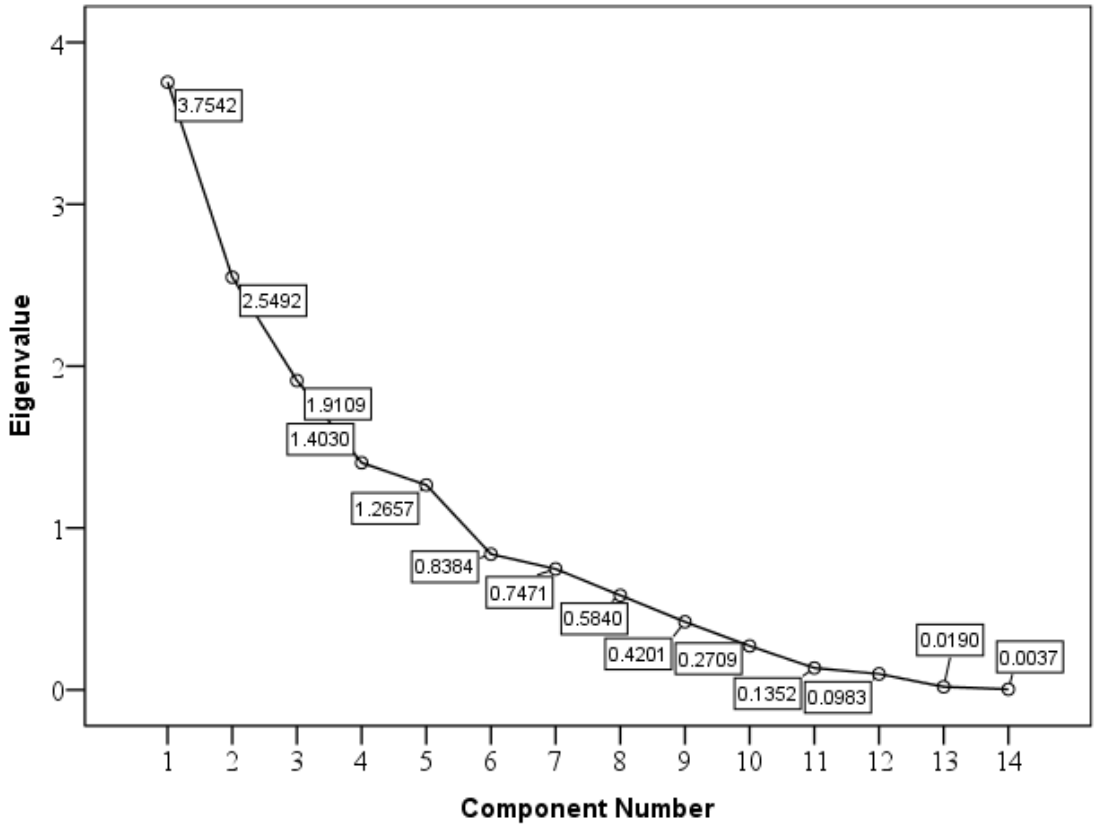


Figure 4.3 Scree plots of principal component analysis

Source: field survey 2014

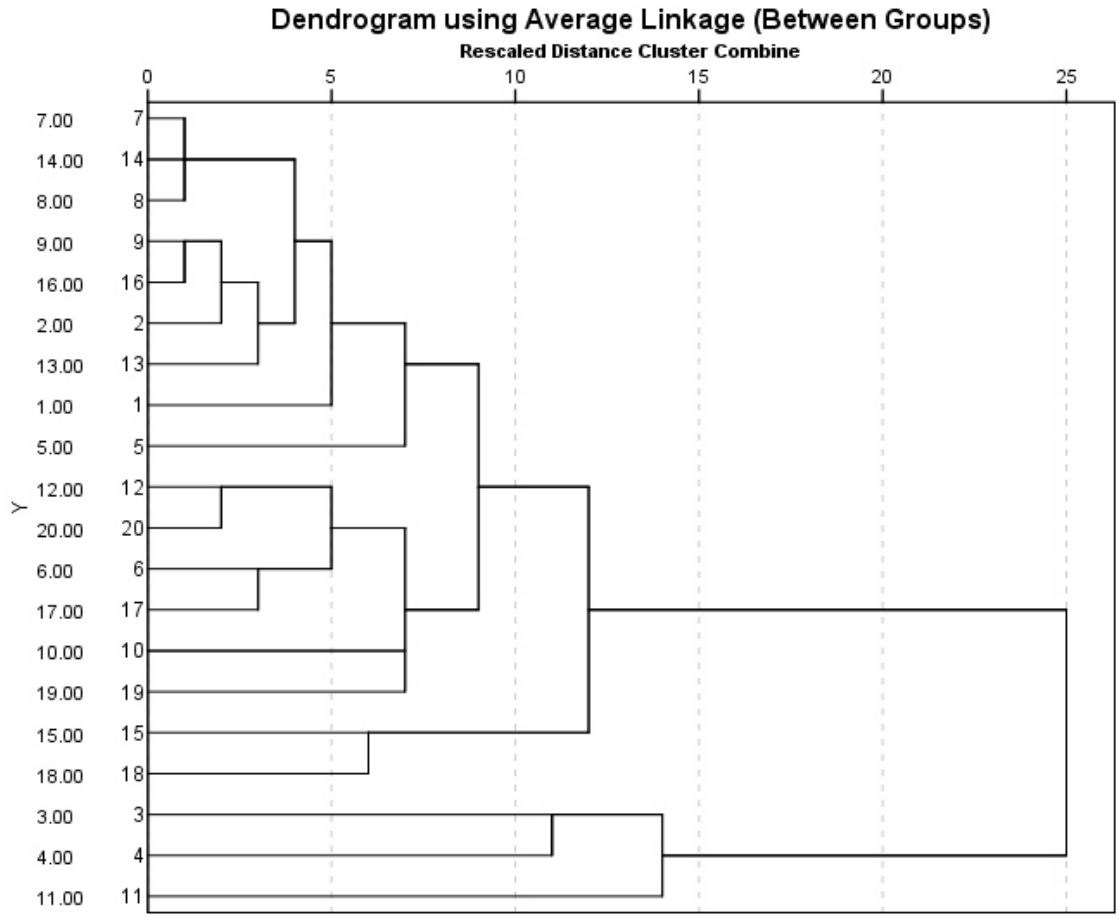
4.3.3 CUSTER ANALYSIS

Is an unsupervised pattern detection method that partitions all case into smaller groups or clusters of relatively similar, cases that are dissimilar to other group (Lattin *et al*., 2003, McKenna, 2003). We applied hierarchical CA on standardized data using Wards method with Squared Euclidean distances.

Cluster analysis (CA) techniques as a useful tool that offers reliable classification of surface/ground water and makes possible adequately to serve for special assessment in an

optimal manner in the basin (Vega et al, 1998, Wu et al, 2010) to survey anthropogenic and natural influences and of characteristics water quality in monitoring stations. Hierarchical agglomerative CA was performed on the normalized data set using the Wards method, Squared Euclidean distance as a measure of similarity. The spatial variability of water quality in the basin was determine from CA. using the linkage distance reported as Dlink/Dmax, which represent the quotient among the linkage distance for a particular case divided by the maximum linkage distance. The quotient is then multiplied by 100 as a way to standardized the linkage distance (Simeonov et al, 2003), Pejman *et al,* 2009).

The result were illustrated in figure 2 where three main groups at (Dlink/Dmax) 100< 70 are visible. The cluster 1 (station Illelar galbi, Basaura, Kimba, Zauro, Dangamaji, Mangoron jega, Matan fada, Huda, Kardi, Asarara, Bayawa ketare, Farfajiya) respectively. These stations receive pollution from mostly rural waste water and agricultural activities. Cluster 2 (station Alwasa, Kiyaki, Galbi and cluster 3 (station Unguwar Dannana, Gulmbe, Kirmi and Bubuche) correspondent to highly polluted sites. Discharge of domestic waste, grazing, fertilizer, irrigation water flush pollutants from crops leach pollutants from soil, animal waste, pesticides and other agricultural chemicals e.g. nutrient, salt.



Source: field survey 2014

Figure 4.4 Hierachical clusters analysis

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 SUMMARY

The aim of this research is to assess the ground water quality with a view to ascertain its current quality status and suitability for irrigation in the flood plains south western sokoto rima basin. The objectives of the research were to determine the physiochemical status of the ground water used for irrigation and to compare result obtained with the set national and international standards.

Water sample from different fadama users association (FUA) where collected after pumping out the water for about 20 minutes so the sample will reflect the from the acquifer.

Fourteen water quality parameters namely PH, Electrical conductivity, dissolves solid, biochemical chemical oxygen demand etc were analyzed in the soil and water laboratory.

Pierson product moment correlation matrix, principal component analysis where employed which explain the variation.

Lastly a hierarchical cluster analysis grouped the study area into three clusters based on the similarity of the tube well water.

5.2 CONCLUSION

Generally, analysis of the groundwater samples showed that they were slightly acidic (6,3) and appears not to have salinity and sodicity problem hazards (EC 0.3). However, due to their low salinity and sodicity problems. With respect to water infiltration into the soils. There Ca, Mg ratios were generally less than 3 and continued use of such waters for irrigation might lead to nutrient imbalances in the soils.

The result from the study indicated that the values for the parameters considered fall within the permissible range. From the foregoing the water may be said to be safe for irrigation. However monitoring of water quality is a basic means of evaluating the sustainability of irrigation system. Regional salinity problems are associated with many factors including

among many others, hydro-geological factors and irrigation practice (Xie et al, 1998). The regional self balance depends on the water balance, therefore all the flow and changes in the salt composition of the soil should be considered.

5.3 RECOMMENDATION

Based on the findings of the study on assessment of water quality for irrigation, some useful recommendations are presented here.

1. There is need either by the government or the collection of the farmer, government and agric allied agencies to adopt appropriate strategies such as provision for leaching and drainage to assist salt accumulation and excess below the plant dept of rooting zone
2. Vigorous extension efforts are required to adequately educate the farmers on proper use of fertilizer with respects to rate, time and method of application. They should be alerted about the potential threat of salinity/ sodicity development in the fedami areas. They should be briefed about the ameliorative/ corrective measures to avert the threat.
3. There is need as a matter of priority to establish a soil and water testing laboratory for continuous monitoring of their quality and for farmers advisory purposes. The information contained in this report would provide the base-lined data.
4. There is need for a collective effort of farmers and extension workers in selecting crop varieties that are tolerant to a particular condition e.g salt tolerance varieties for water with high electrical conductivity.

REFERENCES

Abduljameel, A. (2002) **Evaluation of drinking water quality in Tiru chirapalli** Indian J of Env. Health. 44, 108-112

Acharya G.D., Hath Asha, M.V., Patel, D and Parmarism, K.C (2008) **Chemical properties of ground water in Bhiloda Taluka Region North Gujurat India.**

Adak, M.D. and Purobit, K.M. (2003). Part 1. **Physiochemical Parameters and Water Quality** Index Poll. Ras 22 (1) 133-138.

Adamu, G.K. (2013) **Quality of irrigation water and soil characteristics of Wutari irrigation project** *American J. of Eng. Research (AJER)*

Adeniyi, P.O (1993). **Integration of Remote Sensing and GIS for Agricultural Resource Management in Nigeria**. EARSEL Advances in Remote sensing 2(3): 6-21.

Adeniyi, P.O and Omojola, A. (2009). **Landuse/landcover change evaluation in Sokoto-Rima basin of N.W. Nigeria based on archival remote sensing and GIS techniques**. In Adeniyi, P.O. (Ed). **Geoinformation Technology and Development: a compendium of selected papers** (pp.81 – 111 Lagos Wura-Kay Prints.

Adhikari S., Gupta, S.K., (2008), **Pollutant metal content of vegetable irrigated with sewage water soil sci**. 46: 153-5.

Ajayi, F., Nduru, M. and Oningue, A. (1990), **Halting the salts that kills crops. African Farmer**, No. 4, PP. 10-12.

Ajon, A.I., Utsev J.T and Nnaji C.C (2014), **physicochemical quality of irrigation water in Kastina-ala catchment areas of northern Nigeria**. Curr. World Environment Intn. Research J. of environment sci.

Akan. J.C., Abdulrahaman F.I., Dimari G.A. and Ogugbuarja V.O (2008), **physicochemical determination of pollutant in waste water and vegetable samples along the Jakara waste water channel in Kano metropolis Kano state Nigeria** European journal of scientific research 23 122-133

Amborng, T. (1988), **Where Savanna Turns Into Desert. Rural Development Studies Swedish University of Agricultural Sciences**. Uppsala, Sweden, 150p.

Anita, J and Gita, S (2008) **Physicochemical characteristics groundwater of Sambhar lake city and its adjoining aeas Jaipur district Rajasthan, India**. Int. J. of Chem. Sci. 6; 1793-1799

Anonymous (1993), **Sokoto Environmental Project (SEP) Newsletter No. 4. AP as a case study**. Academic press. "NY. 360p

AWWA (1998). **International Standard Guidelines for irrigation and domestic uses**. In: Anonymous standard method for examination of waste water.

Ayers, R.S and Westcott, D.W (1976), **Water Quality for Agriculture: Irrigation and Drainage** Paper Number 29, FAO Rome, Italy.

Ayers, R.S, and Westcot, D.W.(1985) ,**water quality for irrigation and Drainage paper No 29,** Rev. U . FAO Rome, Italy.

Belan, F. I. (1985) ,**Water Treatment.** Mir. Publishers, Moscow, USSR.232, P.

Bello, K. (2002). **Agriculturalland degradation in Goronyo local government area of sokoto state (B.Sc project)**. Department of Geography, Usman Danfodio Univeristy, Sokoto.

Blench, R. (2000), **Natural Resources Conflict in North Central Nigeria** Cambridge Mallam Dendo Ltd context. Environ. Monit. Assess. 89. 43-67.

Chabukdhara, M., Nema, A., (2012), **Assessment of Heavy metal contamination in Hindo river sediments a characteristics and Geochemical approach**. Chemosphere 87:945-953.

Danazumi, S., and Bichi, M. H., (2010) **Industrial Pollution and Heavy metals profile of Chalawa river in Nigeria.** Journal of appl. Sci and Environ San; 5: 23-29

Danko, M.M, (1997), **Comparative Analysis of some variables of Irrigation Water Quality along River Rima. B. Agriculture Project**. Department of Soil Science and Agricultural Engineering, Usmanu Danfodiyo University Sokoto, Nigeria.

Davis, G. (1982). **Rainfall and Temperature,** in: Abdul, P. and Swindell, (eds).

Davis, G. (1982a). **Relief. In: Abdu, P.S and Swindell, K (Eds). Sokoto state in Maps: an atlas of physical and human resources. Ibadan**: Ibadan university press.

Davis, G. (1982b). **Geology in Abdu P.S and Swindell, K. (Eds) Sokoto state in Maps: an atlas of physical and human resources. Ibadan**: Ibadan university press.

Davis, G. (1982c). **Rainfall and Temperature in Abdu P.S and Swindell, K. (Eds) Sokoto State in maps: an atlas of physical and human resources. Ibadan**: Ibadan university press.

Davis, G. (1982d). **Drainage in Abdu P.S and Swindell, k. (Eds) sokoto state in maps: an Atlas of physical and human resources. Ibadan**: Ibadan university press.

Davis, G. (1982e). **Vegetation in Abdu P.S and Swindell, K. (Eds) Sokoto State in maps: an atla of physical and human resources. Ibadan**: Ibadan university press

Dutta, T.K.,and Majunder, S. (2004), **Studies on seasonal variations in hysic-chemical parameters in Bankura segment of the Dwarakeshwar River (W.B.) India surface water quality in the Kattedan industrial area**, J. of Indian Association

FAO, (1969). **Guidelines: Land Evaluation of irrigated Agriculture**. Soils Bill No 55, FAO Rome

FAO, Food and Agriculture Organization (1969). **Soil and water resources survey of the Sokoto valley, Nigeria final report,** volume V Rome.

George, M.G (2003), **Assessing irrigation water suitability and soil salinity sodicity status at the Kaduna poly demonstration farm Kaduna** MSC thesis Department of Geography Bayero University Kano.

Gill, M.A(1974), **Hydrological characteristics of the Sokoto Rima Basin**. Savanna 3(1): 61-79

Graham, W. B.R., Pishiria, I.W., Ojo, O.I (2006), **Monitoring Ground Water Quality for small scale irrigation**: Case study in South- Western Sokoto Rima Basin, Nigeria

Hussain, I., Hulam, G., Urtaza, M., Abdul, G. H., Hahzad, S., Maqsood, H., Basra, A., Manzoor, Q. A., and Muhammad, S.(2006) **Cadmium contermination of soil and crop by long term use of raw effluent ground canal water for agricultural lands**. Int. J. of Agric. Biol 12: 851-856

Housen, R. A. (1980), **Soil Science Principles and Practice, 2nd Edition,** Brown Company Publishers.

Hussain, H, G., Urtiza M., Abdul, G.H Hahzada Maqsood H., Basra A., Manzor Q.A and Muhammed, S (2006), **Cadmium contamination of soil and crops by long term use of raw effluent ground and canal water for agricultural land**. Int. J. Agric Bio 12: 851-856.

Ganguly, S.,Maiti, S.K. (2002), **Errors in the performance of BOD_3 and BOD_5 tests and its effect on determination of rate constants, Ind.** J of environ protection; 22 (10) 1113-1119.

Jarvie, H.P., Whilton, B.A., Nerl,C. (1998), **Nitrogen and phosphate in east cost British rivers; speciation, sources and biological significance** Sci: total Environment, 210-211

Ibrahim, S.A., Bashir, D., Dikko, A.U (2000), **Evaluation of irrigation water quality in Wurno irrigation project with respect to suitability for irrigation**. Journal of Agric and environment vol. 1: 121-128

Joarder, M. A., Raihan, F., Alam, J. B., Hasanuzzaman, S. (2008) **Regression analysis of groundwater quality data of Sunamjang District, Bangladesh**.Int. J. Environ. Research; 2(3) 291-296

Juahir, H. Zain S.M, Aris, A.Z, Yusoff, M.K, Moktar, M (2009), **Spatial Assessment of Langar River Water Quality Using Chemometrics**. J Environ Monit. 12:287-297.

Khadkar, D.D. and Dixit, A.J. (2008). **Pre-and Post Monsoon Variation in Physicochemical Characteristics of Ground Water Quality in Bhopal, India**. Asian J. Exp. Scie. 22(3).

Koshy M., and Nayar. V.I., (2000) **Water quality aspects of river Pumba at Kozenchery**, Poll Res 19(4)665-668.

Kowalkowski, T., Zbytniewski, R. Szpejna, J. Buszewski, B, (2006), **Application of Chemometric in River Water Classification Water Res.**40: 744-752

Lattin, J., Carroll, D., Green, P, (2003), **Analysis Miltivariate Data.** Duxbury Press, New York.

Liao ,S.W., Gau,H.S., Lai, W.L., Chen, J.J., Lee,C.G. (2007), **Identification of pollution of Tapeng Lagoon from neighbouring rivers using multivariate statistical method**. J. enviro. Manage. 88(2) 286-292

Lone, M.I, Raza, SH., Muhammad, S, Naem, MA, and Khalid, M. (2014), **lead content in soil and wheat tissue along roads with different traffic in Rawalpindi district**. Int. J of Adv. Res. Vol 2

Lui, C.W., Lin, K.H., Kuo, Y.M (2003), **Application of Factor Analysis in the Assessment of Ground Water Quality in Black Foot Disease Area in Taiwan Sci.** Total Envon 313;77-80

Mahvi, A.H, Noari,J.,Bafael, A.A.,Nabaizadeh, R. (2005), **Agricultural activities impacts on ground water nitrate pollution**. Int. J. Envir. Sci .tech 2(1) 41-47

Maiti, S. K. (2002). **Chemical Analysis of Soil in Handbook of Method in Environmental Studies** ABD Publishers pp 142-252.

Maniyar, M. A. (1990) **Evaluation of groundwater quality of bore wells of Gulbarga maintained by KUWS and D. Board** Msc Dissertation submitted to Gulbarga University Gulbarga

Mckenna, J, (2003), **An Enhanced Cluster Analysis Program with Bootstrap Significance Testing for Ecological Community Analysis, Environmental Modelling and Software** 18. 205-220.

Michael, A. M. (1978), **Irrigation Theory and Practice First Edition, Vicas Publishing House**, PVT. New Delhi India 860P.

Michael, A. M. (1985), **Irrigation Principles and Practice Vicas Publishing House, Ltd New Delhi India** PP. 702-720.

Minakshi, DM. Sharms PK., Tur, NS. Harpinder, S., and Kang, GS (2006) **Assessment management and Spatial distribution of ground water for irrigation in**

Rupnagar District of Punjab (India) J. of environ, sci and Eng. Vol 48 No 2 (91-96)

Mishra, A. and Bhatt V.O (2008), **physicochemical and microbiology analysis of under ground water in VV Nagar and Near by place of Anand Gajurat**. India J. of chemistry 5(3)487-492

Mtethiwa, A.,Munyeyenbe, A.,Jere, W.,Ayali,E. (2008), **Efficacy of oxidation ponds in waste water treatment.** Int. J. Env. Res (2) 149-152

Murali, M., Swarupa rano, B. (2005), **Some Studies on Impact of Integrated Lowcost Sanitation on Ground Water Quality Jodugullapolem Slum Area Visakhapatnan**, India Poll, Res. J.24 (1)35-39.

Mustapha, A, Aris A. Z (2012), **Multivariate Statistical Analysis and Environmental Modelling of Heavy Metals Pollution by Industrial Pol**. J. Envion Studoies.21:1359-1367.

Mustapha., A., Nabegu, A.B., (2011), **surface water pollution sources identification using principal component and factor analysis in Getsi river, Kano, Nigeria**. Aust. J Basic and applied science 5:107

Mustapha A. Aris. A.Z (2012), **Spatial Aspect of Surface Water Quality in the Jakara Basin, Nigeria Using Chemometric Analysis**. J. Envion Sci Health A 47;1455-1465.

Mustapha, A, Aris, A.Z.. Juahir, H., Ramli, M.F (2013), **Surface Water Quality Contamination Source Apportionment and Physicochemical Characteristics at the Upper Section of the Jakara Basin Nigeria**. Arabian j of Geosei. 6: 4903-4915.

Mustapha, A. Aris, A.Z. Ramli, M.F., Juahir, H. (2012), **Spatio temporal variation of Surface Water Quality in the downstream region of the Jakara river , Northwestern Nigeria**; A Statistical approach. J Environ Sci Health A 47:1551-1560.

Nair A. G., Mohammed, A . L., and Fadiel, M.M (2005), **hysic-chemical parameters and correlation coefficient of ground water of North East Libya**. Pollutions Res. 24(1), 1-6.

Nazif, W.S., Parveen S. and Saleem I. (2006), **status of micronutrients in soils of district Bhimbar (Azan Jamimu and Kashir)** Agric bio. Sci. 1(2)25-40

Ogheneakpobo, K. (1988), **land use change as a result of the Goronyo dam construction (Bsc Project) department of geography, University of Sokoto**.

Patil P.R, Badgujar S .R and Warke A. M. (2001). Evaluation of Ground Water quality

Pejman, A.H., Nabi-Bidhendi, G.R., Karbassi, A.R. Mehrdadi, N., Ismaeili-Bidhendi, M. (2009). **Evaluation of Spatial and Seasonal variation in Surface water quality using hysic riate statistical techniques**. Int. J Sci Technol. 6:467-476. Pollution for surface water based on a general classification scheme in Indian

Rahananda, M.R., Mohanty, B. P., Bahera Mahananda, N. R.,(2010) **Physicochemical analysis of surface and ground waterof Bargarh district Orissa.** India IJRRAS 2:26-30

RAIN (2008) **RAIN Water Quality Guidelines**. RAIN Foundation. www.rainfoundation.org.

Rani, D.F.G, Geethat, S.and Ebanzor, J (2003), **The drinking water characteristics of fine rural places in and around Thittagudi, Tamal Nadu, India,** Poll. Res 22 (1) 111-115

Roose, E.J. and F Lelong. (1981), **Factor of the chemical composition of seepage and ground water in the inter-tropical zone (West Africa)** J. Hydro. 5:1-2

Sanda, A.R., Samson F. (2014), **irrigation water quality as influence by source along Jega flood plains Kebbi state nig**. Int. journal agric soil sci. vol. 2 (6) 91-93.

Sargaonkar, A. and Deshpande. Y. (2003), **Development of an overall index of pollutionfor surface water based on classifition scheme in Indian context**. Environ Monit.Asses, 89:43-67

Sevilla, J, Lec, C., Lee, B. (2010), **Assessment of Spatial Variations in Surface Water Quality of Kyeongan Stream, South Korea Using Multivariate Statistical Technique**, Sustain Food Water 18:37-48.

Sharma ,S., Vishwakarma, R., Dixit. S.. & Jain.P. (2011), **Evaluation of water quality of Narmada River with reference to physcochemical parameters at Hoshangabad city, MP, India**. Research Journal of Chemical Sciences. 1(3).

Sharma, M.R (2004), **Assessment of ground water quality of Hamirpur area in Himachal Pradesh. Poll,** Res., 23(1), 131-134

Shrestha, S., Kazama, F. (2007), **Assessment of Surface Water Quality Using Multivariate Statistical Techniques**: a case study of Fuji River Basin, Japan. Environ Model Soft 22:464-475.

Shural. H. I. (1980), **Water Quality Management under conditions of scarcity**: Israel

Sial, R., Swamee, P. K., Tyagi, A.,(2005) **Analysis of water indices**. Journal of Environmental Man. 21(2) 161-179

Simeonov,V., Straitis, J.A., Samare, C., Zachariadis, G., Voutsa, D., Anthemidis A.(2003). Assessment of surfsce water quality in north Greece. Water resource. http://dx.doi.org/10.106

Singh, B.R. (2000), **quality of irrigation water in Fadama land of northern Nigeria.** Ground and surface water in Kebbi state nig. Of basic and applied science vol.9 133-142.

Singh, B.R. (2000), **Quality of Irrigation Water in Fadama Lands of Northwestern Nigeria II**. Tube wells water in Zamfara State.

Singh, B.R., Ibrahim, S.A Augie, M.A (2002), **Quality of Tube well water in Sokoto State** Journal of Agriculture and Environment vol. 3 401: 167-174.

Singh, B.R., Tsoho, H.K. (2000), **Quality of Irrigation Water in Fadama lands of North western Nigeria III. Water from Prennial surface bodies Sokoto State Nigeria** J Basic App/Sci. 9:89-98.

Singh, K.P., Malik, A. Mohan, D., Singh, V.K. (2005), **Chemometric data Analysis of Pollutants in Wastewater – a Case Study anal Chin**. Acts 532:15-25.

Singh, M.(2004), **Physicochemical studies of water river Yamuna of Mathura, ECO envi. And conv.**, 10(2): 193-196

Singh, K.P., Malik, A, Mohan., D., Sinha, S., (2004) **Multivariate statistical techniques for the evaluation of spatial and temporal variation in the water quality of Gomti river (india)**. A case study. Water Res. 38;3980-3992.

Sonwane, D.V., Lawande, S.P., Gaikwad, V.B., Kamble, P.N., Kuchekar, S,R.(2009) **Studies on ground water quality around kurkumbh industrialareas Daind, Pune District**

Simeonov, V., Stratis, J., Samara, C., Zachariadis, G., Voutsa, D., Anthemidis, A., Sofonidu, M., Kouimtzis, T., (2003) **Assessement of the surface water quality in Northern Greece**. Water Res. 37:4119-4124

Srinivas, C.H., Piska, R.S., Venkateshwar, C., Rao, M.S.S. and Reddy, P.R.(2000), **Studies on groundwater quality of Hyderabad**. Poll. Res., 19(2) 285-289

Standard Organisation of Nigeria (2007) **Nigerian Industrial Standard: Nigerian Standard for Drinking Water Quality,** SON, Abuja, Nigeria.

Swindell, K. (1982), **Agriculture[1] in the Sokoto Basin '.** In Abdu. P. and Swindell. K.

Swindell, K. (1986), **population and agriculture in the Sokoto Rima Basin of north west Nigeria: a study of political intervention, Adaptation and change,** 1800 – 1980, cashiers d'etudes Africaines 26 (101-102): 75-111.

Tiri, A., Boudhoukha, A. (2010), **Hydrochemical Analysis and Assessment of Surface Water Quality in Koudiat Medour Reservoir, Algeria** Eur J Sci. Res 41:273-285.

Tiwari, T.N. and M. Mishra (1985), **A preliminary assignment of water quality index to major Indian rivers**. Ind. J. Env. Protec., 5(4), 276-279

Thomas, T. H., and Martison, D. B. (2007) **Roofwater Havesting: Handbook for Practitioners.** Delft, T he Netherlands, IRC International Water and Sanitation Center. (Technical Paper Series)

Udo, R. K. (1970). **Geographical Regions of Nigeria**. Heinamann Ibadan.

Unnisa S. A. and Khalilullah. M. (2004), **Impact of industrial pollution on ground and surface water quality in the Kettedan industrial area**. J. of Indian Association for Environ Management, 38:77-80

Varadarajan, N., Purandara B.K (2003), **impact of sewage on ground water quality –case study**. Pollution Res. 22(2)189

Water Resources Institute. WRI (1986), **World Resources 1986 – An Assessment of the Resources base that support the Global Economy**. Basic Books, Inc. NY 245P.

U.S. Salinity Staff Laboratory staff. (1945). **Diagnosis and improvement of saline and Alkali Soils. L.A Richards (Editor), Agriculture Handbook No.60, United States Department of Agriculture, US**. Government Printing Office, Washington D.C.., U.S.A.

Vega, M., Pardo, R, Barrado, E., Deban.L. (1998) **Asseeement of Seasonal and polluting effects on the quality of water by exploiratory dets analysis**. Water Res. 32 (12) 3581-3572.

Wagh, C.V., Kokate, S.J., Aher, H.R., and Kuchekar, S.R.(2009) **Physico-chemical analysis of groundwater in Pravara Area,District Ahmednagar Mahrashtra**. Int J. of Chem. Sci, 2(2)234-242

WHO,(2004)). **International standard guidelines for drinking water in Anonymous standard for drinking water 3rd ed**, Geneva, Switzerland.

WHO, (2008). **Guidelines for Drinking Water Quality**;Third Edition Incorporating the First and Second Agenda, Volume1 Recommendation WHO Geneva www.who.int/water/sanitation/health

Wu,M.I., Wang, Y.S., Sun, C.C., Wang, H.I., Dong, J.D., and Yin, J.P.(2010), **Identification of coastal water quality by statistical analysis method in Daya Bay, South China Sea**. Marine Pollution Bull, 60852-860

Yelwa, S.A., and Eniolorunda, N.B (2012) **simulating the movement of desertification in sokoto and its environs, Nigeria** using IKM SPOT-NDVI data. Environmental Research Journal 6 (3) 175-181.

Appendix I

pH

The pH of tube well water samples was determined by potentiometric method as described by APHA (1985).

The pH determination is usually done by pH meter method that is the most accurate method and free of interference.

pH meters are usually standardized with standard buffer solutions.

pH 4 Buffer solution – Dissolve 1.012 gm anhydrous potassium hydrogen phthalate $KHC_8H_4O_4$ in D.W. and make upto 100ml in volumetric flask.

pH 7 Buffer solution – Dissolve 1.361 gm anhydrous potassium dihydrogen phosphate KH_2SO_4 and 1.420 gm anhydrous disodium hydrogen phosphate Na_2HPO_4 in D.W. and make up to 1000 ml in volumetric flask.

pH 9 Buffer solution – Dissolve 3.81 ml Borax in D.W. and make upto 1000 ml.

Commercial buffer solutions are also available in tablet, powder and conc. Solution forms. These must be dissolved and made upto stated volume with D.W.

Electrical Conductivity

Electrical conductivity is a measure of a waters capacity to convey electric current. The ability of a solution to conduct an electric current is governed by the migration of solutions and is dependant on the nature and number of the ionic species in that solution. This property is called electrical conductivity. Electrical conductivity of a water is directly proportional to its dissolved mineral matter content. The unit of conductivity is micro-siemens (µs/cm).

The conductivity of sample was determined with the help of digital conductometer. The cell constant was determined by placing N/10 Kcal solution in the given conductivity cell.

Sample was taken in a clean beaker and conductivity cell immersed in it and conductivity was measured.

Solids

'Solids' is a term applied to all matter except the water contained in liquid materials and thus definition of solids refers to the matters that remains as residue upon evaporation and drying at a definite temperature.

Total solids is the residue that includes both dissolved solids and suspended solids.

The amount and the nature of dissolved and un-dissolved matter occurring in liquid material vary considerably. Determination of dissolved and un-dissolved matter is made with filtered and unfiltered portions of samples. The un-dissolved matter is usually referred to as 'suspended solid'.

The common practice of determination of solids is to evaporate a suitable volume of the sample in a dish and drying at 105^{o}c followed by weighing. The increase in weight represents the amount of solids. For evaporation, dishes of 50 to 250 ml capacity are employed. Dishes made up of various materials are available such as platinum dish, porcelain dish, silica etc.

a) Total solids:

Clean the evaporating dish and subject to a preliminary drying in an oven at the same temperature intended for residue i.e. about 103^{o}c. Cool in a dessicator and weigh. Place it into a water bath and measure into it 100ml of well mixed sample. Evaporate to dryness and further dry at 103-105^{0}c for one to two hrs in oven. Then cool it in a dessicator and weigh.

$$\text{Mg/L total solids} = \frac{\text{mg total solids} \times 1000}{\text{ml sample}}$$

b) Total Dissolved Solids:

Centrifuge or filter a suitable volume of sample through whatman no. 30 or equivalent filter paper. Evaporate the filtered sample in a dish. Dry the residue at 103- 108^0c or 179- 181^0c. The increase in weight of dish equals the total dissolved solids. It may also be obtained by the difference between total solids and total suspended solids.

Express the result as total dissolved solids on drying at $-^0$c in terms mg/L.

Total hardness

Hardness is the capacity of water for reducing and destroying the lather soap. Hardness in water is due to the natural accumulation of salts from contact with soil and geological formations or it may enter from direct pollution by industrial effluents. Calcium and magnesium are the principle cations causing hardness.

The term total hardness indicates the concentration of calcium and magnesium ions only. The total hardness is expressed in terms of calcium carbonate. Among the methods available for the determination of hardness, The EDTA titrimetric method is precise one and can be performed rapidly.

Reagents:

1. Calcium standard solution- weigh accurately 1.0 gm of pure calcium carbonate and place in a 250 ml conical flask using 50 ml d.w. Add 20 ml 1N Hcl. Warm until the solution is complete. Cool and transfer to 1000 ml volumetric flask and make upto the mark with D.W.

   1 ml=1.0 mg $CaCO_3$

2. Standard EDTA titrant 0.02N- weigh accurately 3.7239A.R. grade disodium ethylene diamine tetra acetate dihydrate (ethylene diamine tetra acetic acid disodium salt EDTA) and dissolve in D.W. and make upto 1000 ml.

   1 ml of exactly 0.02 N EDTA = 1.0 mg $CaCO_3$

3. Ammonia-Ammonium chloride buffer - Dissolve 16.9 gm ammonium chloride in 143 ml conc. ammonia solution. Add 1.25 gm magnesium salt of EDTA and dilute to 250 ml with D.W. Add this solution to 143 ml conc. ammonia solution in which 16.9 gm NH_4cl has already been dissolved. To attain highest accuracy, it has to be adjusted to exact equivalence by appropriate addition of small amount of EDTA or $MgSo_4$.

4. Sodium sulphide inhibitor- Dissolve 5 gm $Na_2S.\ 9H_2O$ or 3.7 gm $Na_2S.\ 5H_2O$ in 100 ml distilled water.

5. Eriochrome black T- indicator-

a. Mix 0.5 to 1 gm of the dye in 100 gm of triethanolamine.

b. Mix together 0.5 gm of the dye and 100 gm sodium chloride to prepare a dry powder mix.

Procedure:

1. Place a suitable volume of sample in a conical flask and dilute to 50 ml.

   For total hardness below 100 mg/L, use 100 ml sample.

   For total hardness greater than 100 mg/L, use 50 ml sample.

   For other, use 25 ml diluted to 50 ml.

   Whatever be the volume of the sample taken, it should not consume more than 15 ml EDTA titrant.

1. Add 1ml buffer solution per 50 ml volume. Add 1 ml sodium sulphide inhibitor if necessary. Add 1 drop of indicator solution or an appropriate of dry powder.

2. Titrate with standard EDTA titrant solution slowly, until a reddish tinge appears and add the last few drops within 3-5 seconds. At the end point, the solution will be blue.

Calcium

Calcium was determined by EDTA titrimetric method.

Reagents:

1. Sodium hydroxide 1 N – Dissolve 40 gm NaoH in about 100 ml d.w. and make upto 100 ml.
2. Murexide indicator (Ammonium purpurate indicator)- Prepared by dissolving 150 mg of the dye in 100 gm absolute ethylene glycol or by grinding 200 mg murexide with 100 gm solid Nacl.
3. Standard EDTA titrant 0.02 N-(see in total hardness).

Procedure:

1. Place in a conical flask 50 ml of sample or a suitable aliquot that consumes not more than 5 ml EDTA titrant. Dilute to 50 ml d.w.
2. Add 2 ml sodium hydroxide solution per 50 ml volume.
3. Add 1-2 gm of indicator if powder is used or 1-2 drops if a solution is used.
4. Titrate immediately with EDTA to proper end point.

Chloride

Reagents:

1. Standard silver nitrate titrant 0.0282 N – Dissolve 4.791 gm silver nitrate in d.w. and make up to 1000 ml in a volumetric flask. Standardise it against 0.0282 N sodium chloride.

2. Standard sodium chloride titrant 0.0282 N – Dissolve 1.648 gm Nacl and make upto 1000 ml in volumetric flask.

   1.00 ml = 1.0 mg Cl

3. Potassium chromate indicator – Dissolve 25 gm potassium chromate K_2CrO_4 in 100 ml d.w.

Procedure:

Place 100 ml of sample or a suitable aliquot containing not more than 10mg. chloride. Add 1 ml potassium chromate indicator solution. Titrate against standard silver nitrate solution with constant stirring until a reddish coloration persist. Conduct a blank by placing 100 ml chloride free distilled water instead of sample. Record the reading.

Dissolved oxygen

Oxygen is dissolved in most waters in varying concentrations. Solubility of oxygen depends on temperature, pressure and salinity of water. It is essential to the life of fish and other aquatic organisms. Test for dissolved oxygen is generally not carried out for unpolluted waters. This test is an indicator of the purity achieved during treatments. Also it is the basis of BOD test.

Iodometric method is used for the determination of dissolved oxygen. Probably Winklers method is used to determine DO.

Apparatus:

Generally BOD bottles of 300 ml capacity are used.

Reagents:

1. Manganous sulphate solution – Dissolve 91.0 gm manganous sulphate monohydrate $MnSO_4 . H_2O$ in distilled water. Filter is necessary. Dilute to 250 ml. 1 ml of this

solution when treated with 50 ml of acidified potassium iodide solution should not liberate iodine.

2. Alkali – iodine – azide reagent –

a. Dissolve 175 g potassium hydroxide and 37.5 gm potassium iodide in distilled water and dilute to 250 ml.

b. Dissolve 2.5 gm sodium azide in 10 ml d.w. Pour the azide solution to alkali – iodide solution and mix well.

3. Conc. sulphuric acid.

4 Phosphoric acid – 85 – 90 %

5. Sodium thiosulphate solution 0.1 N – Dissolve 24.82 gm sodium thiosulphate $Na_2S_2O_3$ $.5H_2O$ in boiled and cooled D.W. and make upto 1000 ml in a volumetric flask.

6. Sodium thiosulphate solution 0.025 N – Dilute appropriate volume of 0.1 N sodium thiosulphate solution to 1000 ml D.W. in volumetric flask.

1.0 ml 0.025 N thiosulphate = 0.2 mg D.O.

7. Starch solution – Prepared by dissolving 1.5 gm starch soluble in 250 ml of D.W., boil for few minutes and keep the solution overnight.

Procedure:

a. Fixation of dissolved oxygen –

Fixation of dissolved oxygen must be performed in the field immediately after the samples has been brought.

1. Take water samples in BOD bottles (of 300 ml capacity)

2. Remove the stopper from sample bottle. Add 1ml of mangnous sulphate solution by inserting tip of pipette just below water surface.
3. Add 1 ml alkaline iodide solution in the same manner. Stopper the bottle without entrainment of air and mix by inverting the bottle at least about 10 times.
4. Allow the precipitate to settle completely leaving a clear supernatant liquid
5. Carefully remove the stopper and add 1 ml of conc. H_2So_4. Stopper the bottle and mix thoroughly until dissolution is complete.

b. Titration –

Take 50 ml of sample in a flask and immediately titrate with 0.025 N sodium thiosulphate to pale yellow colour. Now add 1 ml of starch indicator. Colour of sample turns blue and titration continue till blue colour disappears. Record B.R.

Biochemical Oxygen Demand

Biochemical oxygen demand is a test of great value in the analysis of sewage industrial effluents and grossly polluted water. BOD refers to the quantity of oxygen required by bacteria and other micro organisms in the biochemical degradation and transformation of organic matter under aerobic conditions. The basic principle underlying the BOD determination is the measurement of the dissolved oxygen content of sample before and after 5 days incubation a 20^{o}c.

Reagents:

Same as like for D.O.

Procedure:

BOD of water sample collected during rainy season was determined in the laboratory by following procedure.

Take water sample in BOD bottle. Remove stopper from sample bottle and add 1 ml of $MnSo_4$ solution by inserting tip of pipette just below water surface. Add 1 ml of alkaline iodide solution as same manner. Mix the sample by inverting bottle several times. Allow precipitate to settle down for few minutes. After setting of ppt. clear fluid obtained in the upper portion of bottle.

Take 50 ml of sample in which DO is to be fixed in a flask and titrate with 0.025 N $Na_2S_2O_3$ solutions to form yellow colour. Now add 1ml of starch solution as an indicator and titrate till blue colour disappears. Record B.R.

Remaining water samples from BOD bottle were incubated subsequently at 20oc for 5 days. After 5 days, follow the same procedure and titrate with 0.025 N $Na_2S_2O_3$ solution and record B.R. and calculate D.O.

Reagents:

1. Conditioning reagent- Dissolve 75 gm sodium chloride in 300 ml distilled water. Add 30 ml conc. HCl and 100 ml 95% ethyl alcohol. Add 50 ml glycerol and mix well.
2. Barium chloride crystals.
3. Standard sulphate solution – Dissolve 147.9 mg anhydrous sodium sulphate in distilled water and make upto 1000 ml.

   1.0 ml = 100 μg So_4^{--}

Procedure:

1. Measure 5.0, 10.0, 15.0, 20.0, 25.0, 30.0, 35.0, 40.0 ml of standard sulphate solution and dilute to 100 ml.
2. Add 5.0 ml conditioning reagent and mix well using magnetic stirrer.
3. While stirring, add 0.5 gm barium chloride crystals and continue to stir exactly one minute.

4. Measure the optical density using a spectrophotometer at a wavelength of 420 nm.

5. Carry out a blank determination on the reagents used.

6. Measure a suitable quantity of sample and dilute to 100 ml, add 5.0 ml of conditioning reagent, add 0.5 gm barium chloride crystals and precipitate is obtained.

7. From calibration graph, read the mg of sulphate equivalent to the optical density.

Reagents:

1. Phenolphthalein indicator

2. Sulphuric acid – nitric acid solution - Carefully add 75 ml conc. H_2So_4 to about 150 ml distilled water and cool. Add 1 ml conc. HNO_3 and dilute to 250 ml with D.W.

3. Ammonium molybdate solution –

   a) Dissolve 25 gm ammonium molybdate in about 200 ml D.W.

   b) Add carefully 280 ml conc. H_2So_4 to 400 ml D.W. and cool.

   Add the molybdate solution to diluted acid and dilute to 1000 ml.

4. Stannous chloride solution – Dissolve 2.5 gm stannous chloride in 100 ml glycerol and heat in a water bath. Mix by stirring with glass rod.

5. Phosphate stock solution – Dissolve 439 mg anhydrous potassium dihydrogen phosphate KH_2Po_4 in D.W. and make upto 1000 ml in volumetric flask.

   1.0 ml = 100 µg

6. Phosphate standard solution – Pipette 10 ml phosphate stock solution into 1000 ml volumetric flask and make upto the mark with distilled water.

   1.0 ml = 1 µg

Procedure:

1. Place 100 ml or suitable aliquot of the sample containing not more than 20 µg P in a 100 ml Nessler tube. Add 1 drop of phenolphthalein indicator. If any pink colour appears, destroy it by adding one or two drops of sulphuric _ nitric acid solution.
2. Into a series of 100 ml nesslers tube , pipet appropriate volumes of phosphate working solution covering the range upto 20 g P. Dilute to 100 ml. Include a Nessler tube containing 100 ml distilled water as the blank.
3. o the blank, standard and sample, add 4.0 ml of ammonium molybdate solution and 0.5 ml stannous chloride solution. Mixing after each addition.
4. After 10 min. but before 12 min., measure the colour using a spectrophotometer at 690 nm.
5. Prepare a calibration curve and find out the number of microgram of P equivalent to the observed optical density of the sample.

   Express the result as Mg phosphate as P per liter of sample.

Carbonates and Bicarbonates

Carbonates and Bicarbonates were determined titrimetrically as per Richards (1954).

Reagents:

1. Phenolphthalein indicator: 0.25% solution in 60% ethyl alcohol
2. Methyl orange indicator: 0.5% solution in 95% alcohol
3. Standard sulphuric acid (0.02 N): Dilute 2.8 ml of this solution to again 1 Litre for getting 0.02 N H_2SO_4.

Standardized the solution.

Method:

1. In a porcelain dish 5 ml of the water sample (containing not more than one milliequivalent of carbonate plus bicarbonate) is diluted with distilled water to about 25 ml.
2. A pink colour produced with a few (2 to 3) drops of phenolphthalein indicates presence of carbonate and it is titrated with 0.02 N sulphuric acid until the colour just disappears (phenolphthalein end point) because of alkali carbonate being converted into bicarbonate. This burette reading is designated as b.
3. To the colourless solution from this titration, 1 to 2 drops of methyl orange or methyl red indicator are added and the titration continued till the colour changes from yellow to rose red.
4. Record the final reading which is marked as c.

Appendix II

The mean of the variables was calculated using formula.

Mean value

$$\frac{\sum x}{N}$$

Where X = Total numbers of samples

N= No of samples set

The Pearson correlation coefficient (*r*) can be calculated using the equation below:

$$r\frac{n\sum xy-\left(\sum x\right)\left(\sum y\right)}{\sqrt{\left[n\sum x^2-\left(\sum x\right)^2\right]\left[n\sum y^2-\left(\sum y\right)^2\right]}}$$

Where *r* is the correlation coefficient value, *x* and *y* are the bivariate.

The equations below give the expression of between- and within-column variation:

$$TSS=\sum_{i-1}^{k}\sum_{ni}^{j-1}\left(x_{ij}-x_{++}\right)=(n-1)s^2$$

$$BSS=\frac{\sum(x1)^2}{n1}+\frac{\sum(x2)^2}{n2}+\frac{\left(\sum k\right)}{nk}$$

$$WSS=\sum_{i-1}^{k}\sum_{ni}^{j-1}\left(x_j-x+j\right)^2=\sum_{j}\left(n_j-1\right)s_i^2$$