ASSESSMENT OF THE PERFORMANCE OF WATER SUPPLY SERVICE IN KADUNA NORTH WATER WORKS

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A DISSERTATION PRESENTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY, ZARIA, NIGERIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THEAWARD OF MASTER OF SCIENCE DEGREE IN WATER RESOURCES AND ENVIRONMENTAL ENGINEERING

DEPARTMENT OF WATER RESOURCES AND ENVIRONMENTAL ENGINEERING,
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FEBRUARY, 2017

DECLARATION

I hereby sincerely declare that the work in this dissertation entitled, **"ASSESSMENT OF THE PERFORMANCE OF WATER SUPPLY SERVICE IN KADUNA NORTH WATER WORKS"** was written by me and that it is a record of my research work. It has not, either in part or whole, been submitted by me or anybody for this or any other degree or qualification at this or any other university.

The information derived from literature has been duly acknowledged in the text and a list of references provided.

ABUBAKAR Yebom Musa **……** **……**
(P13EGWR8028) **Signature** **Date**

CERTIFICATION

This dissertation entitled **"ASSESSMENT OF THE PERFORMANCE OF WATER SUPPLY SERVICE IN KADUNA NORTH WATER WORKS"** By Abubakar, Yebom Musa meets the regulation governing the award of degree of M.Sc in Water Resources and Environmental Engineering of the Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literally presentation.

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DEDICATION

This project work is dedicated to Almighty Allah (S.A.W.) the most compassionate, the most merciful who created the human and exalted him above all other creatures.

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All praises and thanks be to Allah, Subhanahu wa ta'ala, the Lord of the A'alameen (mankind, Jinn and all that exists) and peace be upon the Master of all the Messengers, Prophet Muhammad (SAW), may the blessings and peace of Allah be upon him.

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ABBREVIATIONS AND SYMBOLS

%	Percentage
AGM	Assistant General Manager
AWWARF	American Water Works Association Research Foundation
ASI	Adam Smith Institute
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
DA	District Assembly
GOWU	Government Owned Water Utilities
FEPA	Federal Environmental Protection Agency
EC_w	Electrical Conductivity
ESA	External Support Agencies
DO	Dissolved Oxygen
DEA	Data Envelopment Analysis
CWSA	Community Water and Sanitation Agency
GPS	Global Positioning System
hrs	hours
IWA	International Water Association
Km^2	Square Kilometre
KNWW	Kaduna North Water Works
KPI	Key Performance Indicators
KSWB	Kaduna State Water Board
Kw	Kilowatts
m^3	Cubic meter
m^3/h	cubic meter per hour
MDGs	Millennium Development Goals
mg/l	milligram per litre
mm	millimetre
MoWH	Ministry of Works and Housing
NGO	Non-Governmental Organization
MTTR	Minimum Time to Resolve
NTU	Nephelometric Turbidity Unit
NWP	Netherlands Water Partnership

O and M	Operation and Management
pH	Hydrogen Power
PHCN	Power Holding Company of Nigeria
PI	Performance Indicators
PMU	Project Management Units
PO	Private Operator
PPIAF	Public Private Infrastructure Advisory Facility
PPP	Public Private Partnership
PSP	Private Sector Participation
PURC	Public Utilities Regulatory Commission
RA	Regression Analysis
SPEM	Service Performance Evaluation Metric
Sq. Km	Square Kilometre
STWS	Small Town Water Sanitation
SWAs	State Water Agencies
SWOT	Strength, Weaknesses, Opportunities and Threat
TDS	Total Dissolved Solid
UFW	Unaccounted for Water
UN	United Nations
UNCHS	United Nations Centre for Human Settlements
UNDP	United Nations Development Projects
UNEP	United Nations Environmental Protection
UNICEF	United Nations Children Educational Fund
V	Voltage
WB	World Bank
WHO	World Health Organization
WSDB	Water and Sanitation Development Board
WUP	Water Utility Partnership

ABSTRACT

The water supply infrastructure in Kaduna North Water Works (KNWW) has faced alot of problems, partly due to a neglect of the components over a long period and with tariffs at a low level, which was far from reflecting the real cost of the service. Economic efficiency still remains below the regional average, resulting in the lack of financial resources to maintain and extend the infrastructure. This dissertation assessed the challenges facing water supply in the Kaduna North Municipality using a developed performance indicator called Service Standard Performance Metrics (SPEM) and Strength, Weaknesses, Opportunities and Threats (SWOT) analysis. An evaluation using some aspects of technical, financial, human resources and institutional performance indicators was carried out. The results shows that, a prime cause for the water scheme failures to provide the required level of service delivery is poor operation and maintenance practice as well as poor management. In order to establish the basis for developing strategies for the performance improvement plan, a detailed SWOT analysis of the present situation was carried out to identify the Strength, Weakness, Opportunities and Threats of KNWWs. A structured questionnaire along with personal interviews was used to collect primary data from KNWWs staff and households served by the KNWW which was divided into eight baseline communities. The study showed that water supply was being rationed in the Municipality and the major complaint on the quality of water was with the colour. Complaints were mostly made in person (69 %) and the attitude of KNWWs staff to complaints was poor. However, meter readers were generally found not customer friendly by 72.5 % of the respondents. Customers perception of the price of water was average (49.75 %) and an increase in the water tariff without significant improvement in quality would create problems. Finally, some of the reasons for the inefficiency in water delivery from the need assessment carried out were obsolete machines, frequent pipe bursts and power outages among others. The study concluded that water shortages affected both domestic and commercial activities and was a cause of truancy in school children and also accounted for the use of untreated and contaminated water leading to water borne diseases in the municipality. The water quality results obtained are higher in the raining season than the dry season due to the accumulation of sediments.

CHAPTER ONE

INTRODUCTION

1.1 Preamble

The basic functions of water utilities are to construct, operate and maintain water supply systems (Ajibike, 2013). The steps to evaluate the performance of these utilities have been well spelt out by some international organizations such as American Water Works Association in Kayaga, *et al.,* (2004) and Ajibike (2013).

In Kaduna State, acute water shortage has manifested in certain areas of the metropolis particularly Badarawa, Kurmin Mashi, Unguwan Mu'azu, Afaka, Barnawa, Rigasa, Unguwan Sanusi and Nassarawa (Ajibike, 2013).

In the developing countries like United States, where the development of water is mostly government-driven, failure to develop efficient water supply systems has been established as a product of the interplay of several factors (Sulemanova, 2002). Among them, securing finances to build, maintain and expand the systems is perhaps the most important (UNEP, 2002; Hall, 2006). The availability of finance, especially for day-to-day operations and maintenance, is statistical in view of the low level of public finances for urban development, including water supply (WHO, 2000; UNICEF, 2000). In general, water supply in these countries is undertaken by government parastatals that have the dual objectives of providing a social service while generating revenue to offset cost. Ironically, most of these parastatals do not recover their operating expenses from their own revenues, and remain dependent on state governments for subsidies (Hall, 2006). Studies have also confirmed that about half the water in drinking water supply systems in the developing world is lost due to leakage, illegal hook-ups and vandalism (UN, 2002; Hall, 2006). In addition, lack of clear institutional objectives, low wages and poor equipment and supplies

have been widely cited as the typical institutional characteristics of water supply agencies in the developing countries (World Bank, 1994; Franceys, 1993).

The Water Utility Partnership, an organization that deals with capacity building of water supply and sanitation utilities in Africa, has noted that: "public water services in many African countries have been assigned to a single water authority and the abilities of governments to deliver water adequately have been negatively affected by a number of factors like accessible to clean water, disease, etc. Thus urban water systems are characterized by heavy losses both financially and of water itself. Africa is also noted as urbanizing more than any other region in the world. Between 1995 and 2005, the urban population was expected to grow from 300 to 700 million, and by 2020 it is expected that over 50% of the population in African countries will reside in urban areas. Water Utility Partnership (WUP), 2003.

Water utility customers want adequate and a reasonable quality of water service delivery with environmental protection and public health protection at the lowest reasonable cost (AWWARF, 1998). The quality of water delivered and used for households is an important aspect of domestic water supplies, which influences hygiene and therefore public health (WHO, 2003).

The successes of any water utility to satisfy its customers hinge around the efficient operation and proper maintenance of such systems quantitatively and qualitatively with the highest level of consumers' satisfaction (Bernard and Eugene, 2006). The key elements which contribute towards the efficiency of the water utilities of any country are shared vision, values and mission, strategic planning, human resources development, programme development management system, organizational culture, governance, legal/fiscal, compliance, monitoring and evaluation accountability (Islam-UI Haq and Shalid, 2007).

Currently the supply of water is not more than 50 % and 30 % of its effective demand for the urban and rural areas respectively in Kaduna metropolis (Ajibike, 2013).

In spite of the abundant natural water resources, proliferation of water works in the country coupled with a robust policy that spells out strategies and attainable targets, the water situation in Nigeria could best be described as precarious. Over the years, improvement in domestic water supply has not been impressive. For example, in 1990, 47 % of Nigerians have access to improved water. This percentage increased slightly to 53 % in 1991 due to increase in percentage of water coverage. Displaying similar growth rate, only 58 % access was recorded in 2008 (WHO/UNICEF JMP, 2010). The absurdity in water supply situation in Nigeria is further revealed by the fact that urban domestic water supply has been on decline since 1990. For example in 1990, 79 % of the urban dwellers had access. This decreased to 47 % and 45 % in 2000 and 2008 respectively (WHO/UNICEF JMP, 2010). It is pathetic to observe that access to piped water among Nigerians has decreased extensively from 14 % in 1990 to 6 % in 2008 (WHO/UNICEF JMP, 2010).

Water supply shortages and quality deterioration are among the problems which require greater attention and action (Ayoade, 1981). Various strategies are always being developed to make water accessible to all inhabitants. However due to insufficient structures coupled with rapid population growth and urbanization, the gap between demand and supply of water continues to widen (Bernard and Eugene, 2006).

1.2 Statement of Research Problem

The water supply sector in Kaduna State faces a lot of problems, partly due to poor service delivery and operational system. Economic efficiency still remains below the regional average of 62 %, resulting in a lack of financial resources to maintain and extend the

infrastructure. Since the creation of Kaduna North water works under the State Ministry of Water Resources, the sector has been gradually modernized through the creation of an autonomous regulatory agency and introduction of private sector participation, where user participation is encouraged. Hence, there is need for sustainable operation and maintenance. In Kaduna State of Nigeria, where this study of Kaduna North water works is based, the drive towards private sector participation in service delivery and commercializing urban water supply under the National Urban Water Supply Reform Programme is currently progressing most speedily. Although not yet fully implemented, a policy blueprint similar to the one in Lagos state is being outlined towards embarking on full commercial operations by the water board with or without privatization. Signals towards this have for some time been sent out by the Kaduna State Government (although an enabling legislation is yet to be passed). It has been shown that the implementations of reform programmes are not critically done in conjunction or with the knowledge of the consumers. Hence they refused to buy into it. This can be seen in some of its recent policies on water supply tariff and management as well as the various initiatives the Kaduna North Water Works has been involved recently on fully commercializing urban water supply This study assesses the problems and perceptions of consumers on the water services delivery rendered by the Kaduna North Water Works and also complaints about poor water delivery and quality.

In Kaduna, about 75 % of the total populations source their water from the hand dug well (Yari, 2000). If this trend continues, the MDGs on water supply may not be achieved in the Kaduna by the year 2020 in line with MDGs goal. This research seeks to assess the performance of Kaduna state water board with particular reference to Kaduna north water works.

1.3 Aim and Objectives

The aim of this research is the assessment of the performance of water supply service in Kaduna North Water Works, and the objectives achieved for this study are:

i. Identify the major causes of the frequent water shortages (in terms of availability and regularity) in the Kaduna North Municipality.

ii. Carry out the need assessment of Kaduna North water works operations (operation and process)

iii. Determine the Key factors that have impact on the performance of the water service delivery (technical, Operational Maintenance, financial and customer satisfaction).

iv. To assess the general perception (Customers) on the water quality standard delivered to the study area.

1.4 Justification of the Study

This study is expected to identify/contribute, specifically by providing new knowledge, information on Kaduna North urban water supply system. The study will further serve as benchmark data for any further investigation and also as a useful material for academic purposes. It will enable the researcher to assess the expectations of the water quality service delivery and make inputs into the success and sustainability of the projects for Kaduna North Water Woks (KNWW). It will provide useful ideas to better enhance municipal water provision in developing countries. Again the outcomes and the associated outputs of this research would enable KNWW to equip its plant, other sector players, citizens and communities to engage with sector providers and policy makers in providing quality and affordable water locally. This would enable KNWW and partners to contribute to creating

demand and supply side accountability in sector governance. Finally, this study would stimulate research in new and under researched areas that is likely to provide useful data to inform policy making, planning decisions and advocacy efforts at local and other levels.

1.5 Scope of Study and Limitations

Firstly, it is very difficult in Nigeria to elicit official information from individuals and households and even from government departments and agencies Millennium Development Goals (MDGs). As a common thing associated with all household surveys in Nigeria some people feel uncomfortable to divulge the correct and absolute information to researchers for fear of being taxed or arrested by the police. No matter how open a researcher is, some respondents prefer to either hide their identity or not to give out the real information. This might be linked to the literacy level of the population as many people of low education are not well informed and exposed to the full relevance of research. The officials of the Kaduna North Water Works and the Public Utilities Regulatory Commission (PURC) always have heavy schedules. Due to their extra responsibilities as well as travelling and attending conferences, it was difficult to get them to fill their questionnaires. This necessitated the use of emails and telephone calls in some cases to complete the data collection. The study was carried out in the Kaduna North Municipal area which forms the regional capital of the Kaduna State Capital and also forms the central business centre, commercial and industrial part of the Region. The research focuses on the assessment of the residents (i.e. consumers connected to KNWW water system), perception on the quality of water services delivery rendered by KNWW and will also focused on the existing tariff of the Operator (KNWW). The study will be limited to urban areas in Kaduna State with special emphasis on the Kaduna North Municipal area.

CHAPTER TWO

LITERATURE REVIEW

2.1 Background

This chapter, assesses Kaduna North Water Works (KNWW) as a whole, its historical background, management, scope of activities, water sector in Kaduna North, It also covers Gender issues, the future perspectives of water supply, community contribution to the success of Small Town Water and Sanitation (STWS) (Water-Aid National Water Sector Assessment, 2005).

More than 90% of urban water supply in developing countries has been provided by public utilities for many years (UNDP, 2003). However, most of these public managed utilities in the developing countries have been inefficient (Onjali, 2002; WUP, 2001), thus prompting a need for proper evaluation and broad reforms in the public sector in many African countries. The evaluation and reform have been driven by a combination of economic, social and political factors and this have generated the search for efficiency and cost reduction in public service delivery. There is no ironclad definition of utility, otherwise referred to as infrastructure; it refers to all basic inputs into and requirements for proper functioning of the economy and those that enhance the standard of living of the people (Berg and Mugisha, 2004).

2.2 History of Kaduna North Water Works

Since 1993, various reforms has been introduced to address the problems of the sector. The key objectives of the reforms were to separate rural and urban service, to introduce independent regulatory agencies, and to promote private sector participation.

Kaduna North Water Works (KNWW) was established by Edict No. 2 of 1971 as a body Corporate with perpetual succession and common seal and has the power to sue and be sued in its corporate name. This edict was replaced with Kaduna State Water Board law this came into effect on July 1, 2004. The functions of KSWB include:

1) To control and manage all water works

2) To ensure that water is supplied to consumers at reasonable charges and in potable quality and adequate quantity.

3) To enter into agreement or delegate authority for the exercise of any of the functions performed or provided by the Board to increase coverage and quality of service, by encouraging participation of the private sector, communities and Non Governmental Organizations (NGOs) in project identification, planning, design, implementation, financing and management of its water supply systems.

2.2.1 Responsibilities of KSWB

The responsibilities of KSWB include (Kaduna State Water Board, 2007):

1. To produce and distribute water to the people of Kaduna State for domestic, commercial and industrial purposes;

2. To maintain the distribution system;

3. To charge water fees and other services rendered by the Board, with the approval of the State Government, in such a way that the revenue for each year would be sufficient or as nearly as may be to pay for all working expenses.

4. To collect fees for water consumed by customers.

2.2.2 Organizational Structure and Management

The law provides that the Board shall consist of a part – time Chairman and not less than thirteen other members who are appointed by the Executive Governor of the State. The Board members include a representative each from Ministry of Water Resources and Finance, 2 or 3 members who have knowledge in water supply operations and at least 2 persons representing the interest of the consumers. The General Manager is the Chief Executive Officer of the Board. He is assisted by Assistant General Managers in Charge of Administration, Finance, Operation, Projects, Commercial, Corporate Planning, Chief Internal Auditor and Public Relations Manager. Figure 2.1 shows the organogram of KSWB (Kaduna State Water Board, 2007).

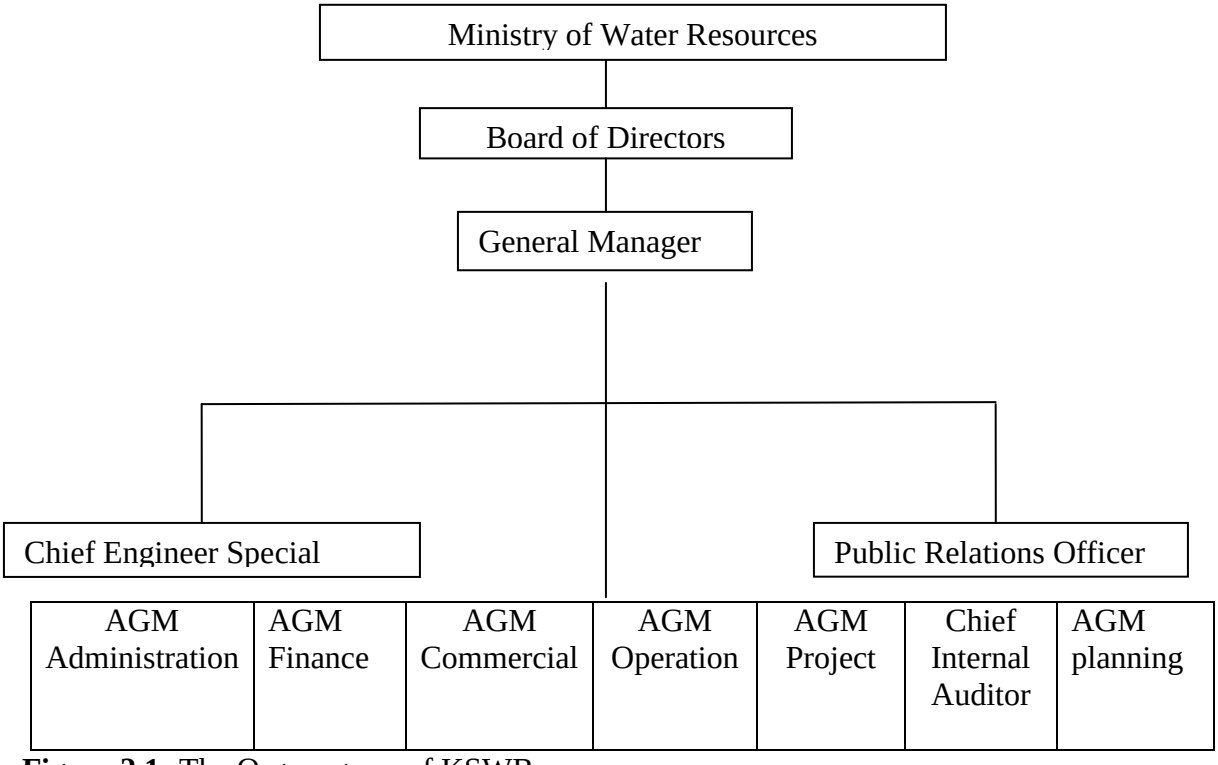


Figure 2.1: The Organogram of KSWB

2.2.3 An Overview of Water Utilities in Kaduna State

Kaduna State Water Board (KSWB) was established in 1971 by Edict No. 2 of 1971 as an autonomous organization responsible for water supply in Kaduna State. Its tariffs recover a part of the operating costs while Government provides subvention to cover the remaining part (about 43%). KSWB's also has foreign debts but loan repayment does not seem to be one of KSWB's main objectives. Recent Government policy indicates that subvention has been stopped and also, KSWB is to repay future loans. Operating costs are rising due to high cost of chemicals, electricity and fuel (Kaduna State Water Board, 2007).

The poor performance of water utilities in Nigerian states cause water shortage problems in most towns and cities. Bukar (1994) identified some reasons for the poor performance, two indicating as follows; poor organizational structures, absence of career opportunities, inappropriate technology, lack of trained staff, insufficient funding, legal framework, adequate structure problems lack of motivation by sector personnel, lack of operation and maintenance culture, inadequate tariff and collection system and political interference or lack of autonomy to State Water Agencies.

There are two treatment plants serving the water supply need of the populace in Kaduna metropolis. These are the Kaduna North Plant at Malali (New and Old plants) and the Kaduna South Plant located downstream of the railway bridge across river Kaduna. Table 2.1 shows the existing reservoirs in Kaduna metropolis and their present status.

Table 2.1: Existing Water Reservoirs in Kaduna North

S/No.	Location	Type of Reservoir	Capacity (m^3)	Date Commissioned	Present Status
1	**Airport**	Braithwaite	2,500	1978	Not Functional
2	**NDA**	Braithwaite	4,800	1975	Functional
3	**Lagard Hall Old**	Braithwaite	4,500	1971	Functional
	Lagard Hall New	Braithwaite	12,700	1971	Functional
4	**Mando**	Concrete	2,500	1984	Functional
5	**State House Kawo**	Concrete	9,100	1971	Functional
6	**Tudun Wada**	Concrete	12,300	1987	Functional
7	**Rigasa**	Concrete	11,000	1986	Functional
8	**UngwanMuazu**	Braithwaite	2,500	1985	Functional

Source: Kaduna State Water Utility Board (2007)

2.3 Partnership forms in Small Towns

According to the Community Waters and Sanitation Agency (CWSA, 2008) report, the following options of partnership are prominent in the small towns' water supply:

a. Public-Public: DA and WSDB with hired professional staff.

b. Public-Private: Agreement between DA/WSDB and PO.

c. Public-Public: Agreement between GWCL and DA/WSDB with hired professional staff. (Franceys and Weitz, 2003) and (Saleh, 2002) also measured partnership's 'added-value' by looking at the benefits that are derived by the partners over time.

2.3.1 Public-Public: DA and WSDB with hired professional staff

According to the Netherlands Water Partnership report (NWP, 2004), in this option the DA transfer the management responsibility of the water system to the WSDB. The WSDB engages service operators to undertake the Operation and Maintenance (O and M)

responsibilities and the board maintains the administrative and oversight management responsibility of the system (NWP, 2004).

2.3.2 Public-Private: DA/WSDB and PO

According to Mitchell *et al.,* (2001) in this option the DA/WSDB (on behalf of the "community") contracts a Project Officer (PO) to manage the water system by undertaking the administration and technical management of the water system (Faulkener, 1997).

According to Axelrod and Dion (1988), partnerships can take many forms, can be used for many purposes and involve complex legal, political, organizational and financial interrelationships among partners (Akintoye *et al.,* 2003).

2.3.3 Public-Public: GWCL and DA/WSDB with hired professional staff

According to the NWP (2004) report, this option consists of GWCL signing an agreement with DA/WSDB to supply bulk treated water (supply is metered). WSDB is then responsible for only the management of the water system i.e. the distribution, tariff setting and revenue collection in the community in which it serves (e.g. Savelugu, Northern Region). Sindane (2000) argues in favour of Public-Public Partnership (PPP) as compared to contractual arrangement where the private takes responsibility for all, or part, of a public function in delivering service to a target group. Partnership as 'deciding together' and 'acting together' (Franceys and Weitz, 2003).

2.4 Actors in Partnerships in the Small Towns' Water Sector

Several groups play a role in partnerships in the water sector: the government at the local level; the formal private sector; and external support agencies. Households also have a role to play but are often left out (Tumusiime and Njiru, 2004). Kayaga and Sansom (2003)

appraise the performance of management contracts in small towns in Uganda. Pessoa, (2008) reports that the involvement of the private sector in the water service delivery requires strong economic regulation to protect the interests of the parties involved. Their study reveals that regulators are normally constrained in their operations since majority of the customers are poor and unconnected at their homes.

2.4.1 The Public Sector

UNCHS (2001) reports that the public sector has its primary strength from its legal authority, law making power, monitoring and regulatory function, and the mandate that it has to act directly with (or delegate responsibility to) other stakeholders. Political interference and corruption, high staff turnover and significant inefficient and inflexible bureaucracy are some weaknesses of the public sector (Shashi *et al*., 2009).

Ministry of Works and Housing (MoWH) – responsible for policy formulation and coordination, for soliciting funding from external support agencies (ESA); monitoring activities of the water supply and sanitation sector, and advising the cabinet (WaterAid, 2005)

2.4.2 The Private Sector

Faulkener (1997) describes the formal private sector as institutions, firms and individuals who may be active in many different aspects of infrastructure management but whose main objective and organization is to generate a profit on their investments. The private sector has strengths in transparency, its ability to innovate and replicate and its customer focus (Caplan, 2001). It is able to respond quickly to the need to improve and deliver services and has limited exposure to political interference. The introduction of Private Sector

Participation (PSP) in the urban water sector is in place under a five-year management contract (WUP, 2001).

The Public Utilities Regulatory Commission (PURC) is the economic regulator of the urban water sector in Nigeria, responsible for setting water rates, establishing regulatory guidelines and protecting the interests of consumers (Nyarko *et al*., 2004). As part of the water privatization process, Adam Smith Institute (ASI), acting as advisor to PURC has identified the need for comprehensive consumer research to aid the development of regulatory policy and guidelines that will protect the interests of all water consumers, in the near future, following implementation of the PSP (Adam Smith Institute, 2002).

According to Addai (2005) poor urban development and population growth is the major cause of this situation in the country. As a result, most homes in the urban cities use water tanks to store water since the taps are not reliable. This condition has led to the evolution of various tanker water supply services. These tankers distribute water to both private and public institutions. Their activities are coordinated by the Tanker Associations and the rate for the private water tankers is determined by the Public Utility Regulatory Commission together with KNWWs (Rudolf, 2005).

2.4.3 External Support Agencies

Huge capital investments in small towns‟ water supply systems require some form of assistance from external agencies outside the locality. External agencies rarely stay for long and only continue their local presence to guarantee the maintenance and expansion of new projects (UNCHS, 2001). A Project Management Unit (PMU) was set up by the World Bank (WB) and the Ministry of Works and Housing to oversee the privatization process. Its

functions “have not been very clear”. It reports to the WB, the Managing Director of KSWB and the Ministry. Based on requests, staff from KSWB were transferred to the PMU, and they were paid better than others” (PPIAF/CWSA, 2001).

Global water problems are attracting increasing attention, not just at the international level, but also within the United States, in its popular press, in natural resource journals and as the subject of books. A prime cause of the global water concern is the ever increasing world population. As populations grow, industrial, agricultural and individual water demands escalate (Mays, 2004).

All too often, water is treated as an infinite free good. Yet even where supplies are sufficient or plentiful, they are increasingly at risk from pollution and rising demand. By 2025, two thirds of the world’s population is likely to live in countries with moderate or severe water shortages. Fierce national competition over water resources has prompted fears that water issues contain the seeds of violent conflict.

But the water problems facing our world need not be only a cause of tension; they can also be a catalyst for cooperation. Two thirds of the world’s major rivers are shared by several States. More than 300 rivers cross national boundaries. Increasingly, countries with expertise in the management of watersheds and flood-plains, or with experience in efficient irrigation, are sharing that knowledge and technology with others. Scientists from many nations and disciplines are pooling their efforts, to assess the threat and in the hope of bringing about a much needed “blue revolution” in agricultural productivity. The organizations of the United Nations system, for their part, in addition to a vast array of

operational projects are also preparing the first edition of the World Water Development Report (United Nations, 2002)

2.4.4 Households

According to Hordijk (2000), the household is the key unit of production, reproduction and consumption, and the unit where decisions on pooling and allocating labour and resources are made (Sulemanova, 2002). Poor households spend considerable amounts of physical, economic and social energies to maintain access potable water supply (George, 2005).

Unsafe water, sanitation and hygiene account for almost 6 % of Disability Adjusted Life Years (DALYs) in high mortality countries. Provision of clean water through municipal or private systems has not yielded the expected health improvements.

The Consumers "Association has run a stakeholders" workshop on the draft management contract. This includes performance measures and incentive targets for serving the poor, taking account of the need to focus on system expansions and not simply on revenues from lifeline tariff billing which could just reflect increased consumption by those already served. Expansions are needed to deal with the present situation in which the urban poor pay water vendors more than 10 times the price paid by those with connections to the piped water network. Government and civil society should respectively ensure and monitor that the management contract to improve the performance of the KSWB equally benefits the poorest people (Benn, 2005)

2.5 Previous Framework for Assessing Partnership

Reviewing the performance of partnerships involves two elements: an assessment of the results of the partnership and an assessment of how the partners work together. Assessing

the results/outcomes is somewhat straight forward. Acutt *et al.,* (2001) provides some quantitative perspectives on costs, benefits and savings of tri-sector partnerships. In this study, the key elements employed in the methodology included: scoping (to identify indicators of partnership benefits); Data collection (to gauge changes in the selected indicators); assessment of incremental contribution of the partnership (to the identified changes); and value for money assessment (comparing net benefits and costs in the partnership process).Other partnership assessment frameworks that have emerged are specifically aimed at assessing the unique characteristics of partnership (Sullivan and Kayaya, 2003).

Provan and Milward (2001) for instance proposed a framework for evaluating public sector networks at three levels: the community, the network, and the organization/participant. At the network level, they mainly suggested structural targets of analysis (e.g. number of partners and number of connections between organizations), or the outcomes of the network (e.g. the range of services provided).

According to Brinkerhoff (2002), their frameworks did not address the quality of the relationships among the partners and how it could be improved for more effectiveness in their outcomes. Mitchell *et al.,* (2001) measured partnership's "added-value" by looking at the benefits that are derived by the partners over time. Caplan *et al.,* (2007) on the other hand, examined partnerships in relation to accountability to better understand their responsiveness, transparency and compliance.

Hasting (1998) in her study on the analysis of power relations in partnerships used data methods such as: attending and recording partnership meetings; conducting interviews with

designated representatives of the partner organisations and collecting minutes; policy documents and other written documents (Pessoa, 2008). Outlines of three vital components of partnerships in this respect by Mcquaid (1994) include:

(a) The mandate, including aims and objectives of the partnership arrangement;

(b) The arrangement within each partnership; and

(c) The various outcomes (Price and Franceys, 2003).

In 2002, Brinkerhoff proposed an assessment approach which covered five general areas: compliance with prerequisites and success factors in partnership relationships; the degree of partnership practice; outcomes of the partnership; partners‟ performance and efficiency (ibid.).

2.6 Measuring the Performance of Water Services

According to Gupta *et al.,* (2006), performance measurement can be defined as an approach to determine how effectively and efficiently a local body delivers the required service. There are two methods of measuring the performance of a system, one is the average analysis or simple ratio measures and the other one which takes into account all the inputs used and outputs produced by the utilities called total factor productivity measures (Gupta *et al.,* 2006). The total factor productivity measures are based on either regression analysis (RA) or Data Envelopment Analysis (DEA) technique. Water and Sanitation Program (WSP) (2006) developed some performance indicators using ratio methods to measure the efficiency of water supply systems. The indicators chosen were investment, financial, billing and collection, quality, costs and staffing, metering, unaccounted for water (UFW), production/consumption, and coverage (Islam-UI-Haq and Shahid, 2007).

UFW is basically the difference between the quantity of water produced and put into the system and quantity consumed or paid by consumers. It comprises of water losses due to leakage, illegal connection and unbilled authorized consumption like water used for cleaning reservoirs and flushing the network system, fire-fighting and water provided free to certain consumer groups and sensitive institutions for example hospitals and schools (Bernard and Eugene, 2006)

2.6.1 Revenue Collection Efficiency

According to (Acutt *et al.,* 2001), sound financing is crucial to long-term operation, maintenance, replacement and expansion. According to Amenga-Etego (2006) the overall income from the water sales should be able to cover operational costs and generate sufficient cash-flow to ensure sustainable long-term operations. Collection efficiency is one of the most important indicators in water supply service delivery that promotes sustainability of the systems but also one of the major shortfalls of many water managers (Ajibike, 2013).

2.6.2 Customer Satisfaction

For any performance measurement system for services in water delivery to be successful, the views of the users of the service is crucial. This is because their level of satisfaction with the services indicates the performance of the system. According to PPIAF/CWSA (2001), high access to the service indicates increased customer satisfaction and consequently their willingness to pay for the water; improved health benefits; and improved revenue collection (cited in CWSA/PPIAF document). The time taken to fetch water at the standpipes is a good measure of accessibility (IWA, 2004).

According to International Water Association (IWA, 2004), "access to good, safe and reliable drinking water is one of the most basic needs of human society and as such requires integrated approach, close cooperation and partnership between all stake holders". IWA (2004), research has shown that access to good, reliable and sufficient water supply increases the health status of people.

2.7 The Problem of Urban Water Supply and the Plight of the Low – Income

The incapacitation of State Water Agencies (SWAs) in meeting the needs for the service delivery is a widespread phenomenon among urban areas in the developing countries. Even at this low level of performance however, the situation is such that the low income earners are always worse off. This creates yet another dimension to the debacle – the question of access to water by the urban poor who in most cases constitute the bulk of the population. The unfolding contradiction is such that while more than two thirds of the urban population belongs to this group – living in informal settlements without adequate connections to the urban water supply systems, they actually pay exorbitant prices for sub – standard sources to meet their basic needs. Meanwhile, the affluent areas are supplied with adequate water for which the residents pay token amounts due to subsidization from the government. "Poor people bear a disproportionate share of the impact of inefficient water supply. Fewer poor people are connected to a network (Kayaga *et al.*, 2004). When they do have access, the installation has to be shared among many people and the prices they pay are among the highest, generally more than those paid by more affluent households connected to the piped systems (McKenzie and Ray, 2009). The price differential is partly a result of inefficiencies, the inequitable practice of subsidizing piped water, lack of scale economies for independent providers, or worse, providers taking advantage of poor people's lack of

choice. But some of the price differential can also reflect the flexibility and convenience of services offered by independent providers – no connection charges or access to quantities of water that are more affordable for poor people" (World Bank Nigeria, 2004).

Service providers find themselves compelled to address the needs of a small group, on whose whims their own survival depends in a chain link that instead of linking them directly to the population being served is veered towards client list intervening forces that includes contractors, managers and staff of the utilities, who are implicated in the clientalist or based on political connections (Kayaga *et al.,* 2004)..

The most critical effect in this relationship is that of the mode of government intervention and its effect on accountability. Network externalities, collective action problems and distributional goals are the usual reasons for the government to be involved in public infrastructure and services in general. When government becomes directly involved by owning and running utility companies as the case of Water supply institutions shows, the arrangements for service delivery are no longer primarily between the consumer and the provider (Kayaga *et al.,* 2004).

2.8 Cost Recovery in Service Delivery

A major concern for sustainability of urban water supply and water resources management in general is the inability of most SWAs to recover costs on existing supplies, which itself is the outcome of the interaction of other factors as examined earlier. The capacity to recover costs may be described as the most important ingredient for the sustainability of any service and is the main indicator of the financial health of the institution providing the service. Cost recovery in urban water supply is basically about recovering all aspects of

costs of providing water, including operations and maintenance (salaries of staff, supplies of inputs, power, distribution, maintenance of plants etc) as well as capital costs (depreciation of major equipment and facilities, distribution network etc).

2.9 Water Service Delivery Systems

Municipal water delivery systems is used to transport potable water from a water treatment plant to residential consumers, for use as drinking, cooking, sanitary conditions, and other water uses in a domestic environment. Water supply is essential for business and industry to operate in a municipal environment. Municipal water systems also may need to provide water for special services that include street cleaning, the selling of water to contractors for erecting buildings, parks and recreation, and miscellaneous uses (Ajibike, 2013).

A water system has two primary requirements: First, it needs to deliver adequate amounts of water to meet consumer consumption requirements plus needed fire flow requirements. Second, the water system needs to be reliable; the required amount of water needs to be available 24 hours a day, 365 days a year (Kayaga *et al.*, 2004)..

The provision of water service delivery is a costly and vexing problem for the State governments and Federal government of Nigeria. In many states of Nigeria, water service delivery coverage is low, resulting in the people patronizing water vendors. Moreover, substantial inefficiencies are typically observed. The provision of urban water service delivery in Nigeria is an essential service which provides a basic good that is critical to life. Urban water services are capital-intensive natural monopolies in Nigeria. Since industrialization, water is typically being provided by the state, till today 95 per cent of water service provision still remains in public hands (Onjali, 2002). In recent times, urban

water service provision has developed a cross-border dimension and global governance has penetrated the water sector.

One solution commonly proposed is to contract water service delivery system of the utilities to the private sector with the belief that service efficiency, high coverage of the water delivery and people's health could be improved.

2.10 Quality of Water Services

Quantitative indicators that measure access to urban water services have the potential of masking the quality of service being provided to homes in Nigeria. Despite low coverage rates, the quality of water services throughout the country continues to decline and is one of the major reasons that diarrhoea and intestinal illnesses are the second leading cause of infant mortality and the leading cause of child mortality in both urban and rural areas, registering rates three times as high as other Latin American countries (Berg and Mugisha, 2004).

In terms of uninterrupted access to water supply, most households in many states of Nigeria receive rationed service and some go more than one day without water service, even if they are connected to the public network. Access to a 24-hour water supply does not exist for customers in the study areas. Widespread intermittent or irregular service provision has forced the urban population to adopt a variety of storage and accumulation strategies. Given this reality, a more realistic parameter for measuring acceptable domestic water supply is daily service with a minimum of 12 hours combined with hygienic storage.

2.11 Efficiency of Water Services

The efficient operation and maintenance of water service systems on the one hand and the

simultaneous pursuit of universal, safe access to these basic services on the other are often incompatible for systems relied upon by a large percentage of low-income customers. In Nigeria, water services face additional constraints caused by poorly performing financial markets that offer few financing mechanisms at high interest rates and a lack of credible enforcement mechanisms to deal with delinquent customers (Areola and Festus, 1997). Even with the benefit of a coherent policy framework, economically viable tariff regimes and a functioning regulatory entity, an enabling environment can still be hampered by a weak national economy, a predominantly low-income customer base and poorly functioning financial markets.

Due to lack of historical data, the operational performance of the system in this analysis is limited to 2002 – 2006. The lack of available historical data again suggests the need for greater efforts in systematic data collection and performance monitoring.

The heart of efficiency of water delivery system is the ability of water service providers to account for the production and delivery of water supply. While leakage and unaccounted for water will never be eliminated altogether, management mechanisms to quantify production and identify losses can be introduced. A billing-to-production ratio comparing the volume billed over the volume produced provides one effective indicator to determine the extent of losses that each water supply system must subsidize.

2.12 Effects of Poor Water Service Delivery System in Nigeria

In many states in Nigeria utilities have inadequate funds to invest in the required expansion of water supply infrastructure, because they have failed to charge reasonable tariffs over a long period. Also, as a result of insufficient pipe – borne water and infrastructure, the rich

and powerful tend to be favoured in the allocation of limited resources and neglect the poor. The consequences of poor water services is that many people invest their time and money in accessing, collecting and storing water from alternative sources and this can be termed coping costs. Added to these coping costs are the indirect costs of both the loss of productive time due to water – related diseases and the costs of medicine to treat them.

Also, higher income consumers incur additional expenditure when they invest in their own well, borehole, pumps and storage tank. During water shortages, the rationing of water affects the poor most adversely as their storage facilities are usually very limited.

2.13 Review of Situational Analysis in Water Utilities

Situational analysis is a management concept that helps water utility to address and prepare for both anticipated and unexpected problems. Situational analysis utilizes asset management to evaluate water utility's current physical situation, and it also evaluates utility systems financial and managerial situation (Ajibike, 2013).

It assists the utility to make fundamental decisions about the purpose, structure and functions of their water utilities systems. In order to make situational analysis planning work, however, utilities need to collect the information that will allow them to make intelligent, informed decision about the purpose, structure and functions of their water utilities systems. Situation analysis is a comprehensive audit of water utility using performance indicators which include: Water produced/year, unaccounted for water, water supply area (%), customer base, metered connections (%), Average water supply, operating ratio and revenue collection efficiency (Islam-UI-Haq and Shahid, 2007) .

2.13.1 SWOT Analysis

SWOT analysis is simply understood as the examination of an organization's internal strengths and weaknesses, and its environment, opportunities, and threats. It is a general tool designed to be used in the preliminary stages of decision – making and as a precursor to strategic planning in various kinds of application (Green, 2003).

SWOT is an acronym for Strengths, Weaknesses, Opportunities, and Threats. A SWOT analysis identifies the organizational strengths, weaknesses, opportunities and threats. It enables the organization to determine the set of their key success factors. That is, those activities or areas in which it must be especially proficient to succeed by fully exploiting the opportunities available to the utility and the areas needed to combat the threats that endanger the utility (Boseman and Phatak, 1989).

A SWOT analysis measures a business unit, a proposition or idea. The SWOT analysis is an extremely useful tool for understanding and decision-making for all sorts of situations in business and organizations. The SWOT analysis headings provide a good framework for reviewing strategy, position and direction of a company or business proposition, or any other idea. SWOT analysis also works well in brainstorming meetings. SWOT analysis can also be used for business planning, strategic planning, competitor evaluation, marketing, business and product development and research reports. A SWOT analysis is a subjective assessment of data which is organized by the SWOT format into a logical order that helps understanding, presentation, discussion and decision-making (Armstrong, 2000). The first step in a SWOT analysis is to make a worksheet by drawing a cross, creating four sectors, and one each for strengths, weaknesses, opportunities, and threats. An outline of a worksheet is shown in Tables 2.2

Table 2.2: SWOT Analysis Worksheet

Potential Internal Strength	**Potential Internal Weakness**
1	1
2	2
3	3
4	4
S	W
O	T
Potential external Opportunities	**Potential external Threats**
1	1
2	2
3	3
4	4

Source: Armstrong, (2000)

2.13.2 International Water Association (IWA) Performance Indicator (PI) System

The IWA PI system is reference system for timely management tool for water services undertakings. The work on the development of this PI started in 1997 and has since progressed through more than 20 scientific and technical meetings in Europe, South America and Africa. The final form of the PI, called performance Indicators for water services, has since 2000 been presented in an IWA manual of Best practices series (Alegre *et al.,* 2001)

2.13.3 SPEM Analysis

The Service Performance Evaluation Metric (SPEM) is a tool designed to adequately appraise the condition of existing schemes vis-à-vis the level of service delivery is being proposed in the study. It is a preliminary approach to get a rational benchmark tool (Armstrong, 2000).

The key performance areas that are normally evaluated by SPEM are operational, financial, institutional and human resources capacity of the water supply scheme as shown in table 2.3 (Armstrong, 2000).

Table 2.3: SPEM Analysis Key Performance Area worksheet

Evaluation Aspect: Key Performance Area	Key Performance Indicator (KPI)
Operational	Maintenance Frequency Maintenance Planning Number of metered connection Spares availability Duration of supply (hr/d) Volume of water produced (m^3 or mgpd) System Capacity Capacity Utilization Unaccounted for water (ufw)
Financial	Funding Billing Efficiency Cash operating ratio collection efficiency
Institutional	Capacity building Partnership Technical Assistance
Human Resources	Number of staff/ 1000 connections Training and Development Customer Centric

Source: Armstrong, (2000)

2.14 Benchmarking Toolkit

The Benchmarking Water and Sanitation Utilities (BWSU), designed primarily for developing regions, includes 27 indicators relating to three (3) factors related to water utilities size, range of service and extent of private sector involvement. BWSU aims at facilitating the sharing of cost and performance information between utilities and between countries by creating a network of linked web sites, through a global partnership (Benn, 2005).

There are four types of benchmarking. They are as follows:

1) **Metric benchmarking** is defined as the quantitative measurement of performance in terms of inputs, outputs, outcomes and the relationship between them. There are four classifications of metric Benchmarking, which are; (i) Total methods or spatial method (ratio), (ii) Frontier or non-frontier, (iii) Parametric or Nonparametric and (iv) Stochastic or deterministic.

2) **Process benchmarking** is defined as the mapping of one's own process and subsequent comparison of the process with those of other companies with exemplary performance in a similar process (Kingdom *et al.*, 1996).

3) Customer Perception Surveys.

4) Model Company Comparisons (Engineering Models)

Advantages of Analysis tools

The following are the advantages of using analysis tools.

1. Easy to use
2. Works without much technical equipment
3. Raises awareness of opportunities, weaknesses and threats
4. Gives the possibility to respond to threats and weaknesses
5. Generates new ideas and strategies

Disadvantages of Analysis tools

The following are the disadvantages of using analysis.

1) The analysis tools are subjective

2) There is a danger of oversimplifying

3) The analysis tools are often performed as a simple list and not reflected and analysed thoroughly

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials

3.1.1 Equipment and Reagents

The following equipment/instruments were used in the analysis of the water quality parameters

Drying oven Gallen kamp, BRIT.No.882942 ENGLAND

Separating funnel, BOROSILICATE 24/20 ENGLAND

Hand gloves, LATEX AGARY PHARMACEUTICAL LIMITED MALAYSIA.

Analytical balance (accuracy ± 0.01gram) Mettler P160N

Double Beam Spectrophotometer AA240fxVarian Company

pH meter, A CRISON MICROPH 2000

HORIBA pH meter model M13

Sterile collection container (Sterile bottle or test tube)

Sterile pipettes or sterile transfer pipettes (Dropper pipettes)

Sterile test-tubes serial dilution

Photometer

Hach Turbidimeter 2100N (Hach Company, Loveland. Co.)

Filter paper- Whatman No 41

Geographical Positioning Systems (GPS)

Conical flask, PYREX 300 ml.

Graduated cylinder, KINMAX USA TD 20 ^{0}C

Pipette, JAYTEC BS 700 TYPE 1 10 ml ENGLAND.

BOD bottles, PYREX USA COVER

Nessler tube, PYREX USA COVER

Autoclave sampling bottles, PYREX USA COVER

Volumetric flask100ml Technico BS 1792 B in 20^{o}C

Ammonium citrate reagent, SG 0.88 Griffin/George Middlesex England

Hydroxyl mine hydrochloride reagent, BDH Chemicals Limited Poole England.

Thymol blue indicator, BDH Chemical Limited ENGLAND product No 21031

Potassium cyanide (KCN) solution, BDH chemicals Limited pool England product No.10201

Ammonium hydroxide ($NH_{40}h$) (analytical grade) BY BOH UK

Sulphuric Acid, BDH pool limited England

Perchloric Acid, BDH pool limited England

(EDTA) ethylendiamine tetra acetate solution (950 g/c) Analytical grade BDHUK

Nitric acid concentration HNO_3 JOSEPHINE BERGERS INTERNATIONAL

Hydrochloric acid concentration HCL, BDH pool Limited England.

Phenolphthalein indicator

Nesslser's Reagent

Stannous Chloride

3.1.2 Description of the Study Area

Kaduna state is located at the centre of Northern Nigeria. Kaduna State covers a land area of 5, 100 Km^2. It has a population of 6, 029,427 (NPC, 2006) and comprises of 23 Local Government Areas. The capital of the state is Kaduna and has a land area covering some 14, 000 hectares with an average density of about 75 persons per squared kilometres. A State-Wide Water Resources Master plan is being developed to improve coverage to more than 70 per cent covering a projected population of 7.1 million by the year 2020. However, with the on-going awareness campaign being intensified for consumers to realize that fund for providing potable water must be generated from the volume of water sold. As such Kaduna State Water Board (one of the 37 SWAs in the country) has been operating as a commercial entity, since 1993, paying for nearly all its operational expenses from internally generated revenue. It has a political significance as the former administrative headquarters of the North Region during the colonial era. The state shares boundaries with Niger State to the west, Katsina and Kano states to the North, Bauchi and Plateau States to the East and FCT Abuja and Nasarawa State to the South. Figure 3.1 shows the map of Kaduna Metropolis, Kaduna State.

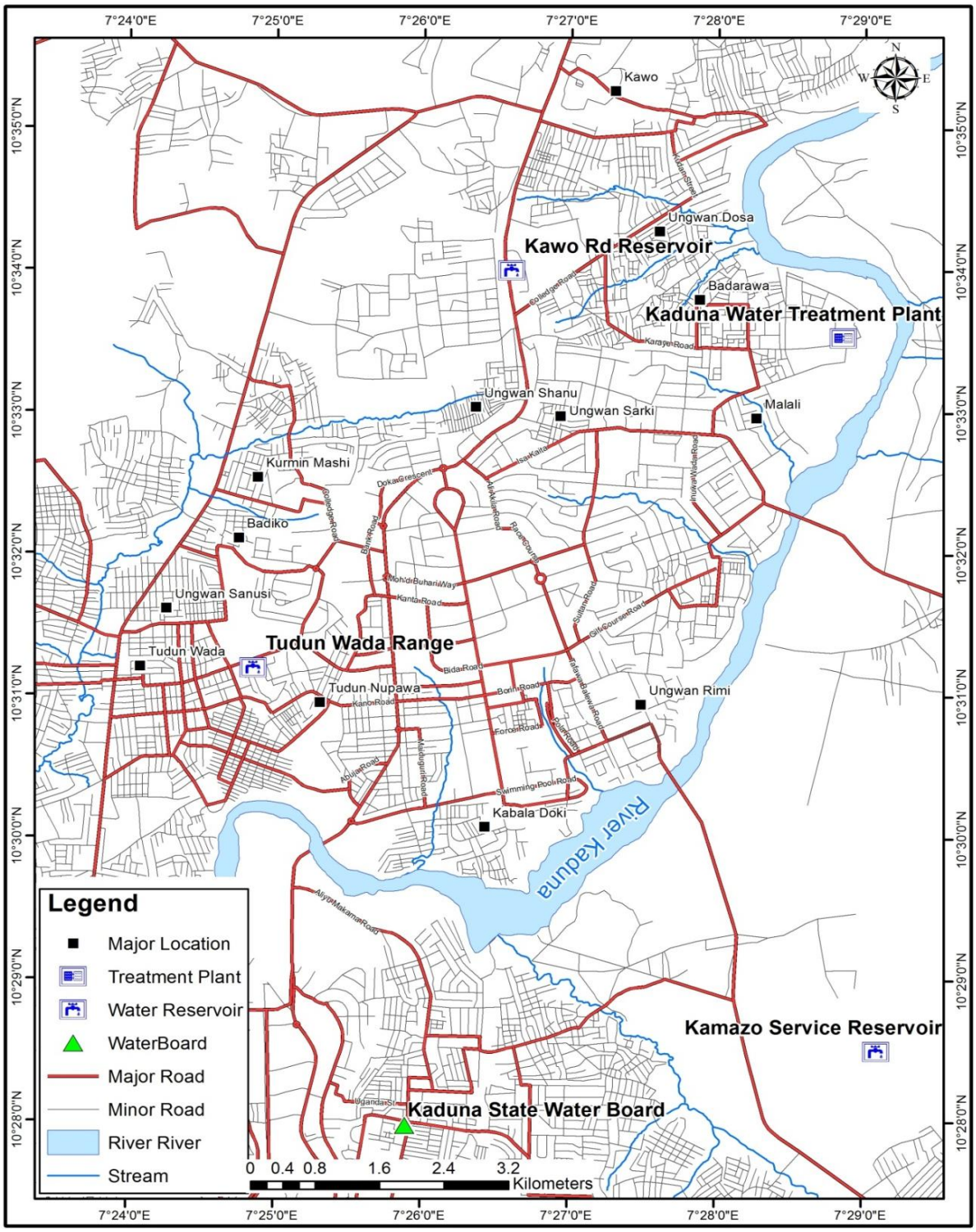


Figure 3.1: Kaduna Metropolis showing locations of the water treatment plant and water reservoirs

Source: Fieldwork/ Modified from the Kaduna Street Map of Kaduna Metropolis

3.2 Methods

3.2.1 Sample collection

Water sample were collected from Kaduna North water works treatment plant at different Unit points namely;

a) Service reservoirs
b) Intake
c) Clear water tank

3.2.2 Sampling procedure

The cluster sampling methods were used in the group stage and systematic approach in sampling to locate the houses. To select, the individual respondents, Incidental interview was granted for the household to avoid biases for the sexes (Saleh, 2002).

A convenient sample of household were drawn from consumers connected to KNWW distribution system to minimize any systematic biases introduced using this particular sampling method. Also, some Commercial and Institutional service category groups who fell in any of the communities were interviewed. The areas were purposively selected due to its strategic position as being in the centre of the town as well as having relevant traits valuable to the study. The systemic sampling procedures were used to select the individual households for the distribution of the questionnaire.

3.2.3 Sample Size

The sample forms a good representation of the population since it was impossible to interview everybody to solicit their views for the study hence the following areas were considered in Kaduna North in addition to 95 members of staff of KNWW:

Table 3.1: Areas and numbers of questionnaires administered

Areas	Number of questionnaires
Airport	50
NDA	50
Lagard Hall	50
Mando	50
State House Kawo	50
Tudun Wada	50
Rigasa	50
Ungwan Muazu	50
Total	**400**

3.2.4 Experimental Laboratory

This section provides the analytic method that was performed in water resources and environmental engineering laboratory of Ahamdu Bello University Zaria. All analyses were performed in accordance with Standard Methods and were conducted within allowable holding times according to Standard Methods (APHA *et al*., 1998). All physical and chemical water quality parameters were measured in duplicate and average results were obtained.

3.2.5 Research plan

The appropriateness of a research methodology in relation to the validity of findings and conclusions cannot be overemphasized. In respect of this, the researcher used the survey method and qualitative research design processes in carrying out the investigations.

3.2.6 Research questionnaire

The primary source of data was obtained from interviewing respondents, observations, from focus group discussions, field visit, and key informants. Interview guides were designed to guide the interview process.

Appropriate data collection method was allowed for collection of complex and rich data. To enable the collection of rich data, semi-structured interview guides were developed and used. Focus groups discussions with key stakeholders and reviewed written reports were used for secondary data collection.

The questionnaires were used to explore respondents‟ attitudes and use patterns by eliciting respondents‟ beliefs, opinions, and behaviours towards the quality of water delivery service. Before executing the survey, several survey questions evaluated by internal and external reviewers to determine whether the wording and responding categories are appropriate for the survey population. In addition, a pilot study was conducted to ensure planning and programming accuracy, effectiveness of interviewer training and ultimately to compensate largely for the expected non-response rate. 50 interviews were collected for each residential area during this piloting phase.

Response options to all attitudinal questions were offered as a fully anchored 5-point Liker scale (“Strongly agree”, “agree”, “neutral”, “Disagree”, and “Strongly disagree”). As many of the questions used different response categories, interviewers are expected to read all the response options to respondents for each question. Questionnaire items that inquired about the frequency of actions, events, or behaviours were initially asked as a simple dichotomous question (“Yes” or “No”) to ensure relevancy of the question to the

respondent. If the response is affirmative, respondents were then asked to report the frequency of occurrences using "open- ended question". Respondents" items for categorical questions were developed individually for each question. Items that required categorical response options fell into two general categories based on whether responses can read or not read to the respondent. For those questions where the response can read, the respondent was asked to select which category (or categories) best described his or her answer.

Interviewers were trained to use the "other" response category to capture response that were either unanticipated or novel. These responses were collected as an open-ended question response and they were subsequently coded with the other response categories during preparation for data analysis. Interviewers were also trained to code non-responsive answers as "Refused" where appropriate.

These engage focus group discussions with the stakeholders including: District Water Board, the Contractor, the District Engineer, Community Water and Sanitation Agency, the District Water and Sanitation Team and the District Assembly.

3.2.7 Administration of questionnaire

Data collection method was: thus it must be "informant consent", sensitive to respondents" rights, ensure fair representation, ensure confidentiality, anonymity and supportive. Research assistants were recruited and trained on effective and efficient ways of administering questionnaires. Permission was sought from the management of the KNWW before questionnaires were administered to the staff. A total of four hundred (400) questionnaires were administered as shown in table (Table 3.1) above.

3.3 Data Analysis

The data collected were coded and sorted into themes (thematic analysis) the analysis and discussions were generally based on the thematic areas. To enhance visual appreciation of data collected descriptive statistical tools such as percentages, bar graphs and cross tabulation were used to present data collected in summarized charts and graphical forms where necessary. The interpretive, discursive, narrative and conversational analytical methods in ascribing meaning to data collected were used. Each of the components was intended to provide insight into the potential application of performance indicators in situational analysis of the scheme. Also, it helped in carrying out the SPEM and SWOT analysis for the scheme.

3.3.1 Service Performance Evaluation Metrics Analysis

The SPEM analysis was used in evaluating the key performance areas operational, financial, institutional and human resources capacity of the water supply scheme. A scoring matrix was used to develop for evaluating each of these key performance areas using some key performance indicators (KPIs).

3.3.1.1 Operational Capacity Evaluation

The information gathered during the administration of the questionnaire, site visits, interviews and consultations are used in the operational evaluation. Eight (8) criteria were used and scored based on the key performance indicator (KPIs). The scoring matrix for the key performance indicators are shown in Table 3.2

Table 3.2: Scoring matrix for Operational capacity

Key Performance Indicator	Key Performance Objective	Frequency
1. Maintenance Frequency	**i.** MTTR fault < 24 hours **ii.** MTTR 24 hours **iii.** MTTR two days **iv.** MTTR three days **v.** MTTR one week	
2. Maintenance Planning	**i.** Monthly routine maintenance established **ii.** Routine maintenance carried out one day after the scheduled date. **iii.** Routine maintenance carried out two days after the scheduled date. **iv.** Routine maintenance carried out one week after the scheduled date. **v.** No routine maintenance schedule established	
3. Number of metered connection	**i.** Above 20,000 **ii.** 16,000 - 19,000 **iii.** 11,000 - 15,000 **iv.** 6,000 -10,000 **v.** 1,000 - 5, 000	
4. Number of Service connection	**i.** Above 20,000 **ii.** 9,000 - 10,000 **iii.** 7,000 - 8,000 **iv.** 5,000 - 6,000 **v.** 1,000 - 4,000	
5. System Capacity Utilization	**i.** 90 - 100 % **ii.** 70 - 89 % **iii.** 50 - 69 % **iv.** 30 - 49 % **v.** 10 - 29 %	
6. Duration of Supply	**i.** 20 - 24 hr/d **ii.** 15 - 19 hr/d **iii.** 10 - 14 hr/d **iv.** 9 - 13 hr/d **v.** 2 - 8 hr/d	

MTTR = Minimum Time To Resolve (Maintenance Problem)

7. Volume of water Produced (m^3)	**i.** Above 60, 000
	ii. 1,000 - 9,900
	iii. 40,000 - 59, 000
	iv. 10,000 - 19,000
	v. 0 - 9,000
8. Unaccounted for Water	**i.** 5 – 25 (%)
	ii. 26 – 35 (%)
	iii. 36 – 45 (%)
	iv. 46 – 55 (%)
	v.56 – 75 (%)

Table 3.2: Continued
MTTR = Minimum Time to Resolve (Maintenance Problem)

3.3.1.2 Financial Capacity Evaluation

The financial aspect of the evaluation is to show whether or not the level of financing is adequate enough to meet the expected level of service delivery as well as meeting the requirements of operating costs. Table 3.3 shows the matrix format for financial capacity evaluations.

Table 3.3: Scoring matrix for Financial capacity Evaluation

Key Performance Indicator	Key Performance Objective	Frequency
1. Funding	**i.** Funds were adequate to meet system Upgrades and operating Costs.	
	ii. Funds adequate only for system upgrades	
	iii. Funds Only sufficient for operational costs	
	iv. Fund available to cater only for minor repairs	
	v. Funds not enough to meet operational needs.	
2. Billing (%)	**i.** 90 – 100	
	ii. 70 – 89	
	iii. 50 – 69	
	iv. 30 – 49	
	v. 10 – 29	
3. Collection Efficiency	**i.** 90 – 100	
	ii. 70 – 89	
	iii. 50 – 69	
	iv. 30 – 49	
	v. 10 – 29	
4. Financial Efficiency	**i.** 3 Months	
	ii. 3 – 6 Months	
	iii. 7 -10 Months	
	iv. 10 – 12 Months	
	v. Above 12 Months	

3.3.1.3 Institutional Capacity Evaluations

The institutional aspect considers building partnerships among water schemes with other sector institutions for training and research, management skills and utility management as shown in Table 3.4

Table 3.4: Scoring matrix for Institutional capacity Evaluation

Key Performance Indicator	Key Performance Objective	Frequency
1. Capacity Building Partnership	**i.** Strong partnership exists between federal, State, the Board and external agency **ii.** Strong partnership exists between federal, State and District Utilities. **iii.** Partnership exists between State, External agency and District Utilities. **iv.** Partnership exists between State District Utilities. **v.** No partnership exists	
2.Technical Assistance	**i.** Technical service level agreement exists between State, external agency and Board **ii.** Technical service level agreement exists between external agency, Board and District Utilities **iii.** Technical service level agreement exists between Board and District Utilities **iv.** Technical service level agreement exists between external agency and District Utilities **v.** No technical service level agreement exists.	
Total		

3.3.1.4 Human Resources Capacity Evaluations

The human resources capacity evaluation addresses the present staff strength, competencies other factors in the day to day administration of these scheme. Table 3.5 highlighted the evaluation aspects.

Table 3.5: Scoring matrix for Human Resources Capacity Evaluation

Key Performance Indicator	Key Performance Objective	Frequency
1. Number of Staff/1000 Connection (Persons)	**i.** 10 – 15 **ii.** 16 – 21 **iii.** 22 – 27 **iv.** 23 -28 **v.** 29 - 34	
2. Training and Development	**i.** Staff attend courses quarterly **ii.** Staff attend courses twice annually **iii.** Staff attend courses once a year **iv.** No training/workshop or seminar attended	
3. Customer Centric	**i.** Excellent **ii.** Very Good **iii.** Good **iv.** Fair **v.** Poor	
Total		

3.3.2 SWOT Analysis

SWOT is an acronym for Strengths, Weaknesses, Opportunities, and Threats. SWOT analysis templates were used to identify the organizational strengths, weaknesses, opportunities and threats. It enables the organization to determine the set of their key success factors. SWOT analysis template is shown in Table 3.6

Table 3.6: SWOT Analysis Template

Strength	**Weaknesses**
Advantages of proposition? Capabilities? Competitive advantages? Resources, Assets, People? Experience, knowledge, data? Financial reserves, likely returns? Marketing-reach, distribution, awareness? Location and geographical? Price, value, quality? Qualifications, certifications? Processes, systems, IT, communications? Cultural, attitudinal, behavioural? Management cover, succession?	Disadvantages of proposition? Gaps in capabilities? Lack of competitive strength? Reputation, presence and reach? Financials? Timescales, deadlines and pressures? Cash flow, start-up cash-drain? Continuity, supply chain robustness? Effects on core activities, distraction? Reliability of data, plan predictability? Morale, commitment, leadership? Accreditations, etc? Processes and systems, etc?
Opportunities	**Threats**
Market developments? Competitors' vulnerabilities? Industry or lifestyle trends? Technology development and innovation? Global influences? New markets, vertical, horizontal? Geographical, export, import? Business and product development? Information and research? Partnerships, agencies, distribution? Volumes, production, economies? Seasonal, weather, fashion influences?	Political effects? Legislative effects? Environmental effects? IT developments? Competitor intentions - various? Market demand? New technologies, services, ideas? Vital contracts and partners? Sustaining internal capabilities? Obstacles faced? Insurmountable weaknesses? Loss of key staff? Sustainable financial backing? Economy - home, abroad? Seasonality, weather effects?

3.4 Population and Water Demand

3.4.1 Population development

The population of Kaduna was forecasted using two methods; the arithmetic method of forecasting which is based upon on the hypothesis that the rate of increase is constant. It is usually expressed as (Shundar, 2007).

$$P_t = P_o + K_a t \quad 3.1$$

$$K_a = \frac{P_2 - P_1}{t_2 - t_1} \quad 3.2$$

Where,

P_t = Population at future time

P_o = Present population usually represented as P_2.

And the hypothesis of constant percentage or geometric growth rate which assumes that the rate of increase is proportional to population. It can be written as; (Shundar, 2007)

$$lnp_t = lnp_2 + k_p(t - t_2) \quad 3.3$$

$$k_p = \frac{ln_{p2} - ln_{p1}}{t_2 - t_1} \quad 3.4$$

3.5 Water Quality

Water samples for laboratory analysis were taken from the raw water source and treatment plants were carried out to determine their quality characteristics. The results for treated water samples compared favourably with WHO 1994 standards and the Nigeria National Standards (FEPA, 1991) for drinking water. However within the distribution network, colour and turbidity of water reaching the consumers were found respectively. Furthermore, the Physical, chemical and bacteriological examination of the water samples from service outlets were determined.

3.6 Water Quality Analysis

Several parameters were analyzed when determining water quality of Kaduna North Water works (public water sources). This section describes the parameters that were analyzed and their significance. These parameters include a physical (pH, Temperature, Turbidity, Conductivity) chemical (Dissolved Oxygen, Total Dissolved Solid, Suspended Solid), and microbiological (COD, BOD) constituent that were analyzed on the water samples for the research.

3.6.1 Physical parameters of water quality

The physical parameters that were determined are;

pH

Conductivity

Temperature

Turbidity

3.6.2 Chemical Parameters of water quality

The chemical parameters that were determined are;

Dissolved Oxygen

Total Dissolved Solid

Suspended Solids

Chemical Oxygen Demand (COD)

Biological Oxygen Demand (BOD)

Nitrate

Chlorine residuals

3.7 Two Way Analysis of Variance

It is also referred to as complete randomized block design with one observation per cell. It is use when handling heterogeneous data, which lead to the introduction of the blocking effect. It is called two way, because both the treatment and block are considered for the analysis that is the variability of the both treatment and block are checked. the sum of squares total (SST) are splited into sum of square treatment (SSt), sum of a square block (SSb) and sum of square error (SSE) The model is thus;

$Y_{ij} = \mu + \alpha_i + \beta_j + e_{ij}$

$i = 1, 2, \ldots, k$

$j = 1, 2, \ldots, b$

Assumption of the Term

1. All observations must be independent of one another
2. $\sum \alpha_i = \sum \beta_j = 0$
3. $\sigma_1^2 = \sigma_2^2 = \ldots \sigma_k^2$
4. $e_{ij} \sim N(0, \sigma^2)$

HYPOTHESIS

For treatment

H_0: there is no significant difference among the treatments

H_1: there is significant difference among the treatments

For block

H_0: there is no significant difference among the blocks

H_1: there is significant difference among blocks

Level of Significance

$\alpha = 5\% = 0.05$

TEST STATISTIC

For Treatment; $F_{Cal} = \frac{MSt}{MSE}$

For Block; $F_{Tab} = \frac{MSb}{MSE}$

Decision Criteria

Reject H0, Fcal > Ftab on all cases

Table 3.7: Analysis of Variance (ANOVA)

Source of Variation	**Degree of Freedom**	**Sum of Squares**	**Mean Square**	**F**
Treatment	K – 1	SSt	MSt	$\frac{MSt}{MSE}$
Block	B – 1	SSb	MSb	$\frac{MSt}{MSE}$
Error	(K - 1)(b - 1)	SSE	MSE	
TOTAL	**Bk – 1**	**SST**		

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Background

This chapter covers the analysis and interpretation of data collected through field research, stakeholder forum, site visits and personal observation for the study. The data collected from the staff of Kaduna North Waterworks was analyzed separately since their questions were different. The information presented in this chapter serves as input for the discussions and interpretation.

4.2 Respondents Characteristics from Questionnaire

4.2.1 Demographic Data

The demographic distribution as illustrated by Figure 4.1 plotted from appendix A (Table A1) revealed 75.87 % of the respondents interviewed were “below 25 years” whilst 96.29 % of the respondents were between the ages “25 - 40 years” and 27.84 % of the respondents were “above 40 years”. This means that the respondents interviewed in the Kaduna North Municipality were adults so their views may be taken as a true reflection of the water service delivery situation. Generally, there were as many men as females.

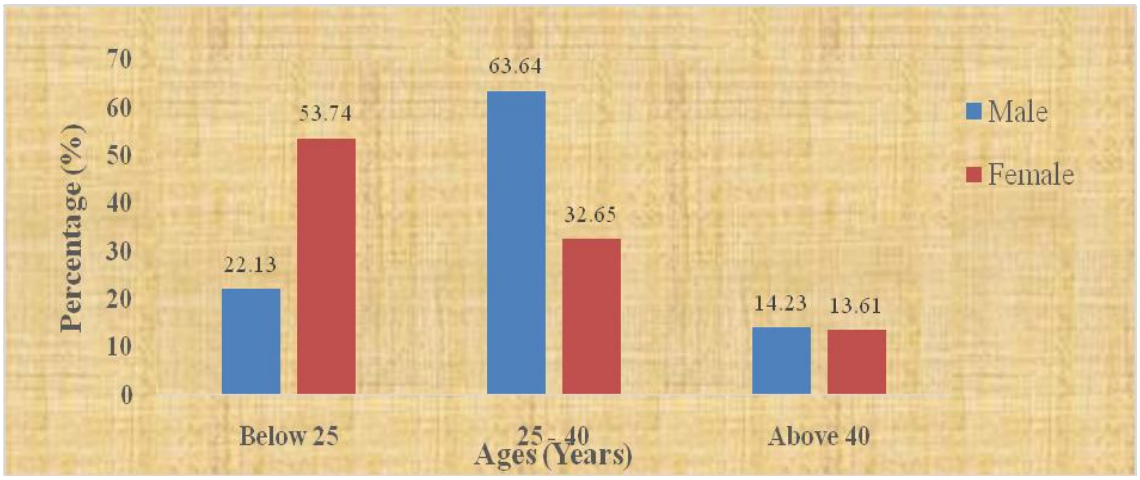


Figure 4.1: Gender and Age distribution of respondents

4.2.2 Educational level of Respondents

The educational levels of the respondents as depicted in Figure 4.2 (Appendix A, Table A2) show that, 22.00 % had tertiary education, (46.50 %) of the respondents have had secondary level education, 25.75 % of the respondents had basic level education with 5.75 % of them with no formal education at all. Relatively, majority of the respondents (94.25 %) have had some form of education which facilitated their understanding of the questions upon which they were able to make informed contributions.

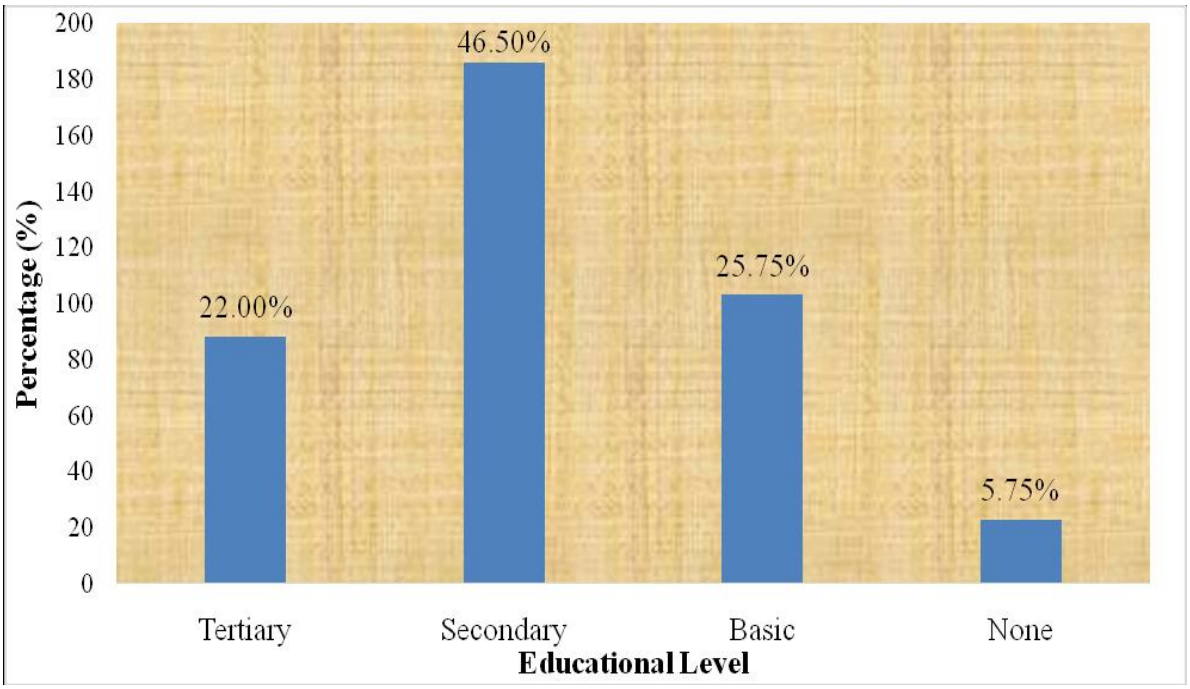


Figure 4.2: Respondents of Educational Level

4.3 Flow Condition

4.3.1 Household Size

The researcher sought to know the number of people living in a house to determine their water consumption. Table 4.1 shows that the dominant house hold size was 7 to 9 (31 %) followed by 4 to 6 (26 %) and more than 9 persons (22 %). Most the households with 1 to 3 (21 %) were located in the below average income community.

Table 4.1: Unit Household Size

Household Size/Community	1-3	(%)	4 - 6	(%)	7 -9	(%)	More than 9	(%)
Airport	10	20	12	24	16	32	12	24
NDA	8	16	10	20	24	48	8	16
Lagard Hall	12	24	13	26	15	30	10	20
Mando	8	16	18	36	9	18	15	30
State House Kawo	9	18	14	28	16	32	11	22

Tudun Wada	12	24	13	26	10	20	15	30
Rigasa	10	20	12	24	17	34	11	22
Ungwan Muazu	14	28	13	26	16	32	7	14
Total	**83**	**21**	**105**	**26**	**123**	**31**	**89**	**22**

4.3.2 Consumer Assessment on Water flow Condition (Reliability)

Three main time periods were used in assessing the flow of water in a day, that is the dawn flows (0 - 8 GMT), the daytime flows (8 - 16 GMT) and the night flows (16 – 24 GMT). Figure 4.3 (Appendix A; Plotted from Table A3) shows that 49.5% of the respondents received water supply at dawn 0 – 8hrs GMT in a day whilst 36.75 % received water supply within 8 – 16 GMT (daytime) and 13.75 % also received water supply within 16 - 24 GMT (night time) in a day. The intermittent flow of water could be attributed to the demand exceeding supply for which reason supply of water has to be rationed. Additionally, about 256 connections are added to Kaduna North Waterworks network per year which reduces the pressure of flow at peak periods thereby worsening the situation.

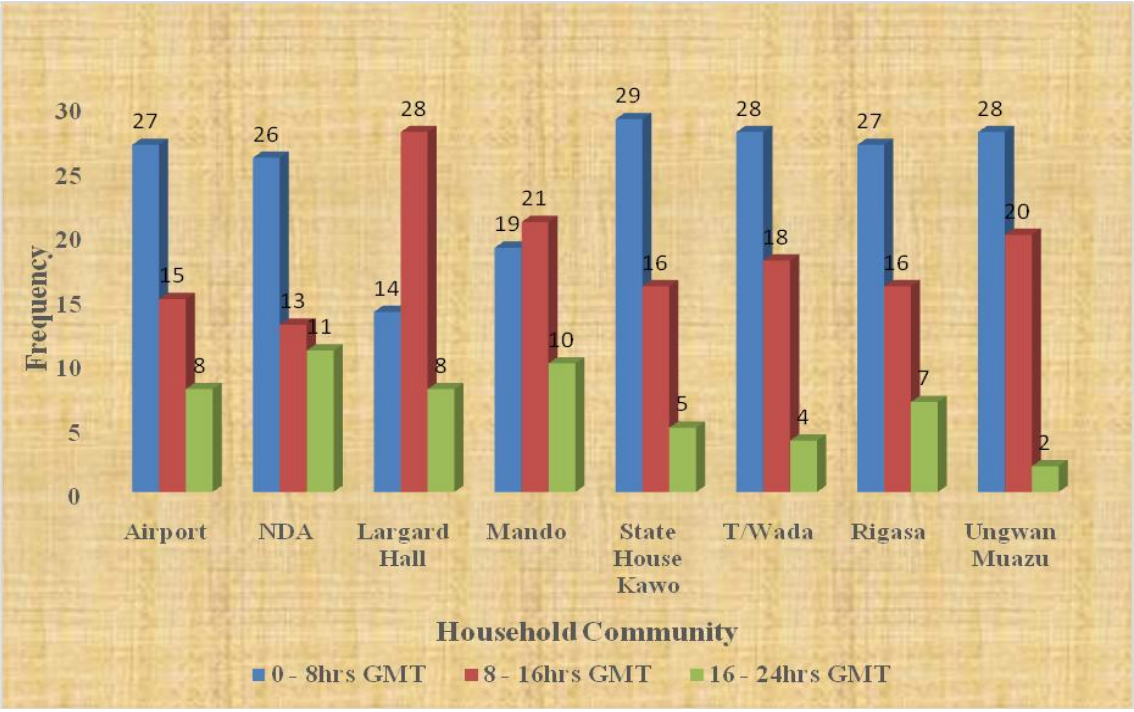


Figure 4.3: Hours of Flow in a day

4.3.3 Customer Perception about the KNWW Flow Satisfaction

This part wanted to assess customers‟ perception on their satisfaction of the flow situation. KNWW consumers were asked questions “How will you grade the level of flow satisfaction of water delivery” in a 5 point grading system (“Excellent”, “Good”, “Fair”, and “Poor”). The study confirmed that the benefits of the KNWW participation (Public-Private partnership) had yielded some desirable results in the flow satisfaction in the municipality of Kaduna North Waterworks. Figure 4.4 (Appendix A; Plotted from Table A4) shows that consumers were satisfied (Excellent, Good) with the service delivery with a perception of 16 % and 30 % were indifferent grading as fair 35 % while 19 % graded as poor.

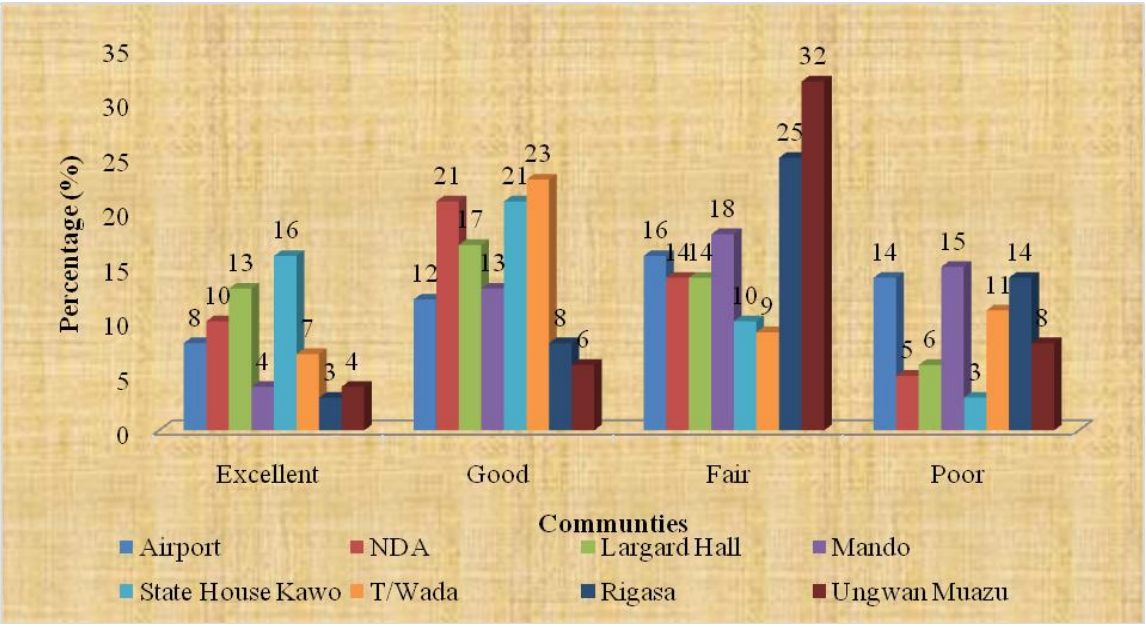


Figure 4.4: Consumers Assessment on Satisfaction of flow Condition

4.4 Customer Perception about Quality of Water

A separate physical water quality parameters (i.e., Taste, Smell, Colour) is presented in Figure 4.5, Figure 4.6 and Figure 4.7 (Plotted from Table A5, A6 and A7; Appendix A) respectively. For this comparison, questions regarding physical quality of water, the researcher used a 4 point grading system ("Excellent", "Good", "Fair", and "Poor"). Here, respondents were expected to indicate which best described their impression about the water quality.

On the question of the taste of water, the study revealed that consumers were generally satisfied with the taste (36.25 %) rating it as good, (15.5 %) as excellent, (36.5%) as Fair and (11.75%) as Poor.

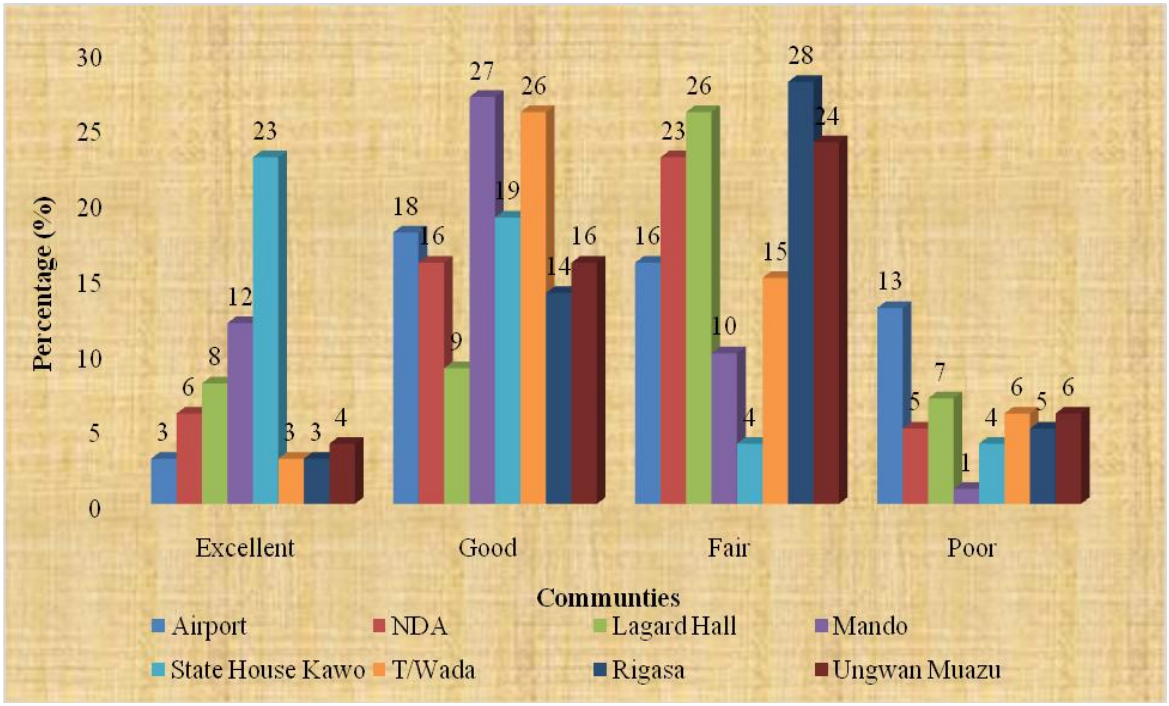


Figure 4.5: Consumers Perception on Taste of water

On the question of the smell of water, the study revealed that consumers were generally satisfied with the smell. This is shown in Figure 4.6 where 21 % said it was excellent, 53 % graded it as good whereas 18 % and 8 % rated it fair and poor respectively.

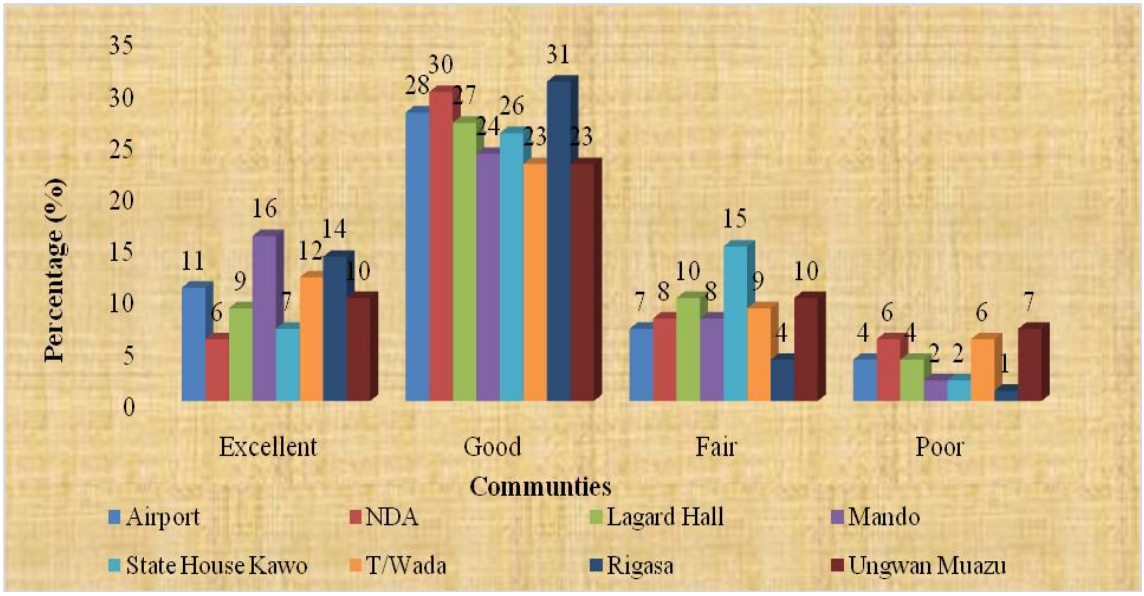


Figure 4.6: Consumers Perception on Smell of water

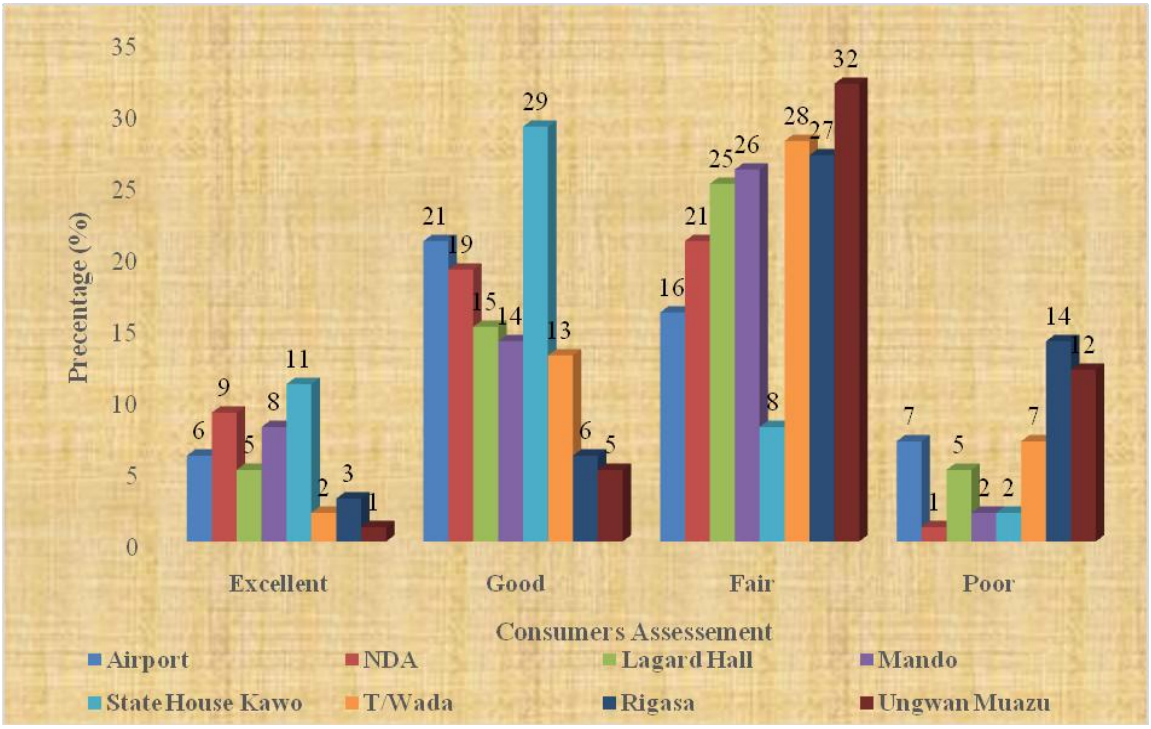


Figure 4.7: Consumers Perception on Colour of water

Finally, from Figure 4.7, majority of consumers were not satisfied with the colour of the water as (11.25 %, 30.5 %, 45.75 % and 12.5 %) Excellent, Good, Fair and poor respectively. This major parameter basically affected negatively from the consumers‟ perception the overall impression of the physical quality of water delivered to them.

The study revealed that the water colour was greatly affected after any form of service interruption. Also, the colour of the water looked brownish with instances where tiny particles were seen in the water making most consumers store the water and allowing it to settle before usage. For this reason, the general satisfaction about physical quality of water was low.

Another possible reason could be due to leakages which were left unattended to in some areas leading to water supply system under vacuum conditions drawing foul water into the pipes (McIntosh, 2003).

4.5 Customer Impression about the Water Bill

The study asked respondents about their impression of the cost of water with a four point grading system (e.g., Low, Average, High and Very High). The study used responses from customers to examine the fairness of water tariff since water pricing is an important criterion for ensuring financial sustainability of the service. Figure 4.8 (Plotted from Table A8, Appendix A) shows an indication of customers perception of the rating of Kaduna North Waterworks (KNWW) bills. It came to light that the majority of respondents (49.75 %) said it was average, 27.75 % said it was high and 9.5% said very high while another 13 % said it was low. Those who said it was very high and high happen to be those who live in multi-occupancy houses.

The Kaduna North Waterworks (KNWW) tariff is the lowest of all the water service providers. The existing lifeline tariff generally does not benefit the poor. High-income customers residing in single-family houses pay the lowest rate per meter cubed (m^3) of water and receive the highest subsidy whilst consuming the highest quantity per person. The lowest income customer residing in multi-occupancy houses pay the highest Kaduna North Waterworks (KNWW) rate per meter cubed of water whilst consuming the lowest quantity per person (Nyarko, 2008). This is reflected in the reason why customers consider bills to be on the higher side. The limit for domestic unit is exceeded due to the multi-unit houses in one compound and hence higher charges are paid per extra units of water used.

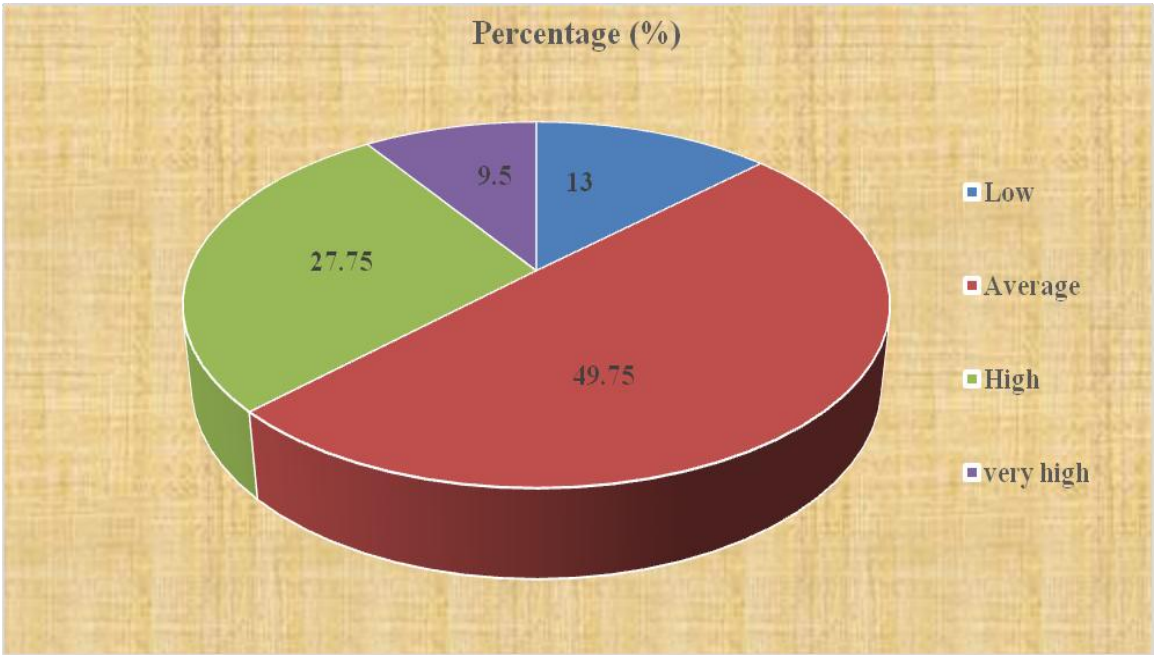


Figure 4.8: Consumers Perception about billing

4.6 Customer Perception on Customer Care

4.6.1 Customer Assessment on Mode of Complaints

It is important to emphasize that, out of the 400 customers interviewed, they responded to have made complaints to the Customer Care unit using the available Kaduna North Waterworks (KNWW) modes. On this basis the analysis was made.

Bureaucratic situation at Kaduna North Waterworks

A customer of Kaduna North Waterworks may forward complaints through the following means:

A. By Phone

B. Personal report to office (District or Regional Office)

C. Public Utility Regulatory Commission (PURC)

A. *By Phone:* Customers may contact the Kaduna North Waterworks (KNWW) office on the toll free number. This toll free number connects the caller to a Front office (Head office). The call centre picks details/particulars of complaints/complainants. Depending on

the caller's destination, the respective Regional Back Offices are contacted. The Back Office forwards complain to the District office that then moves to assess the nature of the problem. The District office then gives a situational report to the Back Office (at the Regional office) which then forwards the report for approval through the Front Office. Figure 4.9 shows that 31 % of the KNWWs customers reported complain through the KNWWs call office.

B. ***Personal report to office:*** Persons may also report at the Regional or District offices personally. The nature of complain is noted and investigated. Assessment report from the District office is sent to the Regional office who then forwards the report through messaging to the Head offices for approval. The study showed that 69 % of the KNWWs customers reported their respective complains through the KNWWs Regional or District Offices.

C. PURC*:* The PURC ACT (*THE PUBLIC UTILITIES REGULATORY COMMISSION ACT, 1997 Or ACT 538*) is an Act to provide for the establishment of a Public Utilities Regulatory Commission to regulate and oversee the provision of utility services by public utilities to consumers and to provide for related matters. Figure 4.9 (Plotted from Table A9, Appendix A) indicates that none of the respondents complained through the PURC.

It could then be emphasized that majority of KNWWs customers directly make complains about the water service delivery in person by reporting to the Regional or the District offices. The research found out that though the use of telephone for making complain was less used. Also the study results revealed that all the customers interviewed had no knowledge about channelling their complaints through PURC. The study suggests that the PURC could intensify education to create public awareness about their duty as a means of channeling complaints.

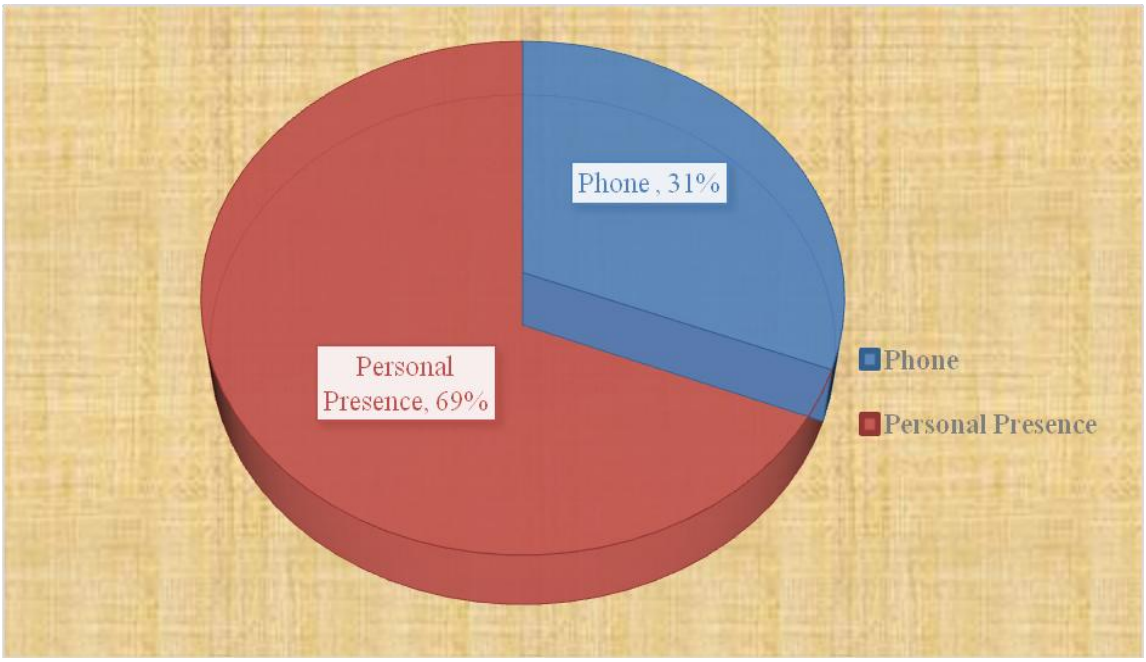


Figure 4.9: Customers mode of complain

Table A9 from the Appendix A shows the distribution and break down of the responses to the mode of complaint within the eight communities.

4.6.2 Customer Satisfaction with Responses

Customers were subsequently asked the question “Did you get a satisfactory response”? An average response was determined and the study revealed 67 % as shown in Figure 4.10, plotted from Table A10; Appendix A, were not satisfied with the way KNWWs responded to complaints. This could be due to both the nature and the long delay complaints are channelled before achieving the desired solution.

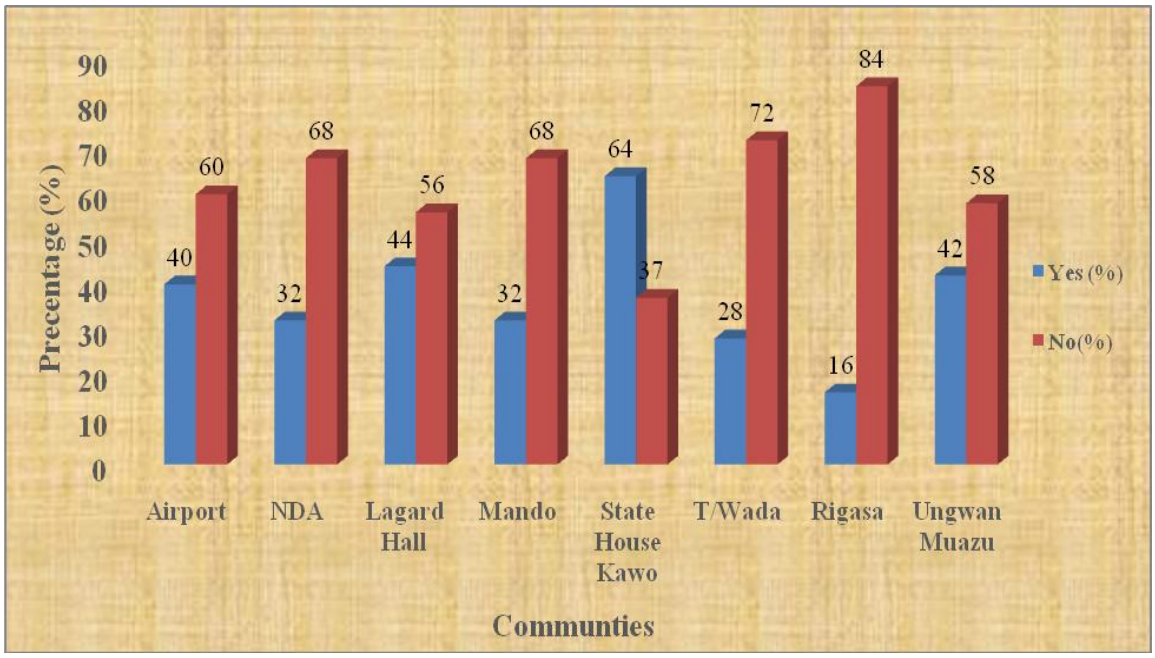


Figure 4.10: Customer Satisfaction

For further analysis putting emphasis on the various communities, Table A10 (Appendix A) the distribution of the responses using a simple dichotomous ("Yes" and "No") response.

4.6.3 Customer Perception on Notification of Service Interruption

Figure 4.11 (Plotted from Table A11, Appendix A) shows consumers' perception on notification of service interruption throughout the various communities. 15.25 % out of the 400 questionnaire expressed their satisfaction as Excellent of notification of service interruption, 36.25 % as Good, 38.25 % as Fair and 10.25 % as Poor. Generally, satisfaction (Good, Fair) with notification of service interruption was skewed in favour. Public awareness campaign could be intensified especially for consumers in the middle and high income communities since their perception was much lower. It could then be said that public addressing activity goes on better in the low income areas than the high and middle income areas.

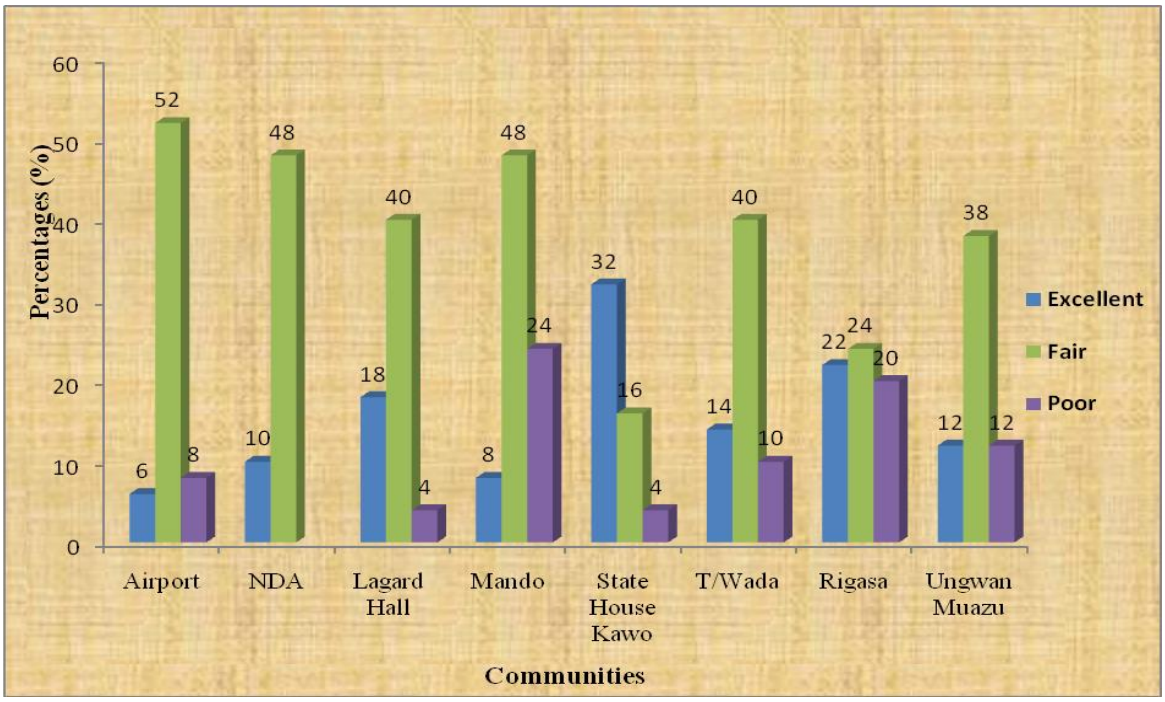


Figure 4.11: Consumers Assessment on Notification of Service Interruption

4.6.4 Customer Assessment on Attitude of KNWWs Meter Staff

This section assessed customer satisfaction of the services of KNWWs personnel specifically the meter readers as shown in Figure 4.12. Others include bill distributors, leakage detection unit, cashiers at pay points and repairs/maintenance division. The views expressed by respondents about the meter/bill staff were generally positive with 27.5 % of them indicating their satisfaction as good and 41.5 % were fair. The general complaints and comments from a few customers (31 %) had to do with individual friction between staff and customers as poor.

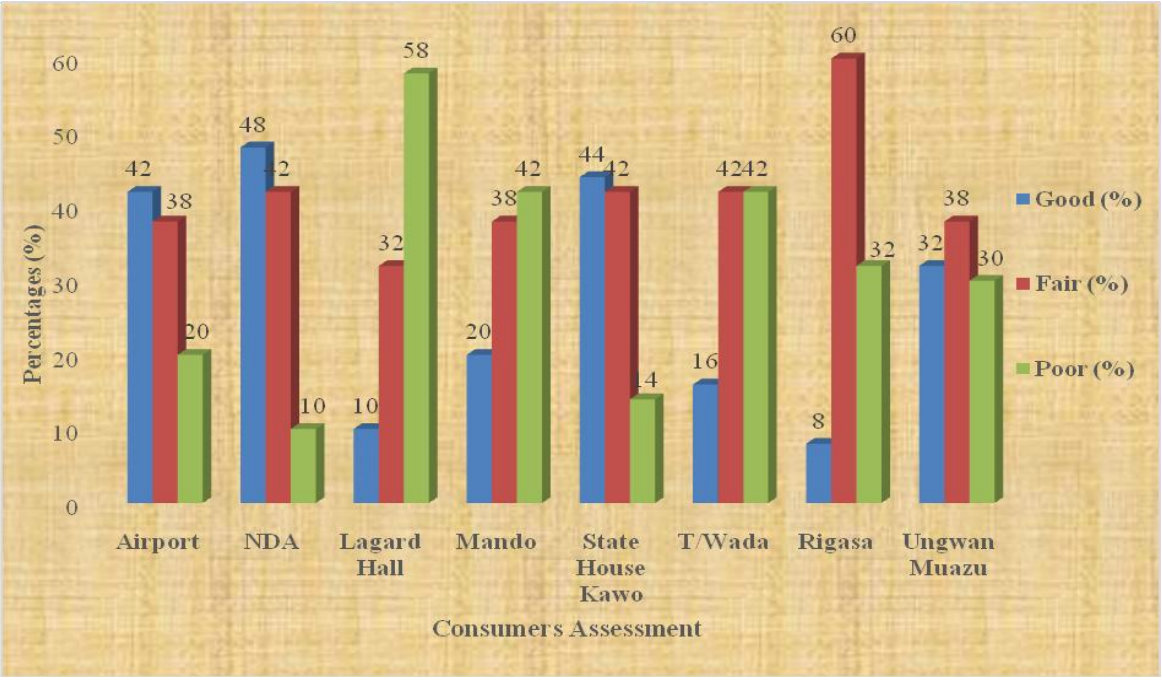


Figure 4.12: Consumers Assessment on the meter Readers

4.7 Issues with Water Shortages

Respondents were presented with the possible impact of the water shortages for ranking as listed in Table 4.2. A majority of the respondents (94 %) saw water shortages slowing down both domestic and commercial activities within the communities as a problem which was negatively affecting their lives.

On the issue of the amount of time lost in search of water, 84 % said it was a problem and only 15 % did not agree on the issue of the amount of time lost in search of water.

Another issue had to do with lateness and absenteeism of children to school. Water shortages often led to school children citing it as the reason for their absence from school and 86 % of the respondents agreed that it was a problem when these children had to go in search of water before attending school. Children risk their lives especially when their source of water is a stream or well leading to loss of lives and injuries and this was

supported by 70 % of the respondents saying it was a severe problem and another 22 % saying it was a minor problem.

Majority of the respondents (80 %) said there was the risk of using untreated water from wells and streams during prolonged water shortages in the communities. This was a problem to them since almost every activity from domestic to commercial had to do with water. This puts their lives at risk of consuming contaminated water in the preparation of especially food by unscrupulous vendors.

Table 4.2: Issues with water shortages

Issues	**Severe Problem**	**%**	**Minor Problem**	**%**	**Not a Problem**	**%**	**Don't Know**	**%**
Slows down domestic and commercial activities	256	**64**	120	**30**	12	**3**	12	**3**
High water charges from water vendors	120	**30**	200	**50**	60	**15**	20	**5**
Too much time wasted in search of water	180	**45**	160	**40**	60	**15**	-	**-**
Long queues in fetching water leading to quarrels	210	**53**	112	**28**	40	**10**	38	**9**
Reason for lateness and absenteeism in school children	240	**60**	104	**26**	46	**12**	10	**2**
Children risk their lives searching for water	280	**70**	90	**22**	16	**4**	14	**4**
Leads to hike in prices of food items	50	**12**	170	**43**	160	**40**	20	**5**
Risk in using untreated water from streams and wells	200	**50**	120	**30**	65	**16**	15	**4**

4.8 ANALYSES OF RESPONSES BY THE KNWWs STAFF

4.8.1 Demographic Data of KNWWs Staffs

Of the 95 members of staff interviewed, 25 (26 %) were females and 70 (74 %) were males. There were 26 males between the ages 18 to 25years and 6 females, also 29 males between 26 to 35years and 13 females. There were 9 males between 36 to 45years and 4 females

between 36 to 45years while there were 6 males and 2 females above 45years respectively as shown in Tables B1 (Appendix B) and presented in Figure 4.13

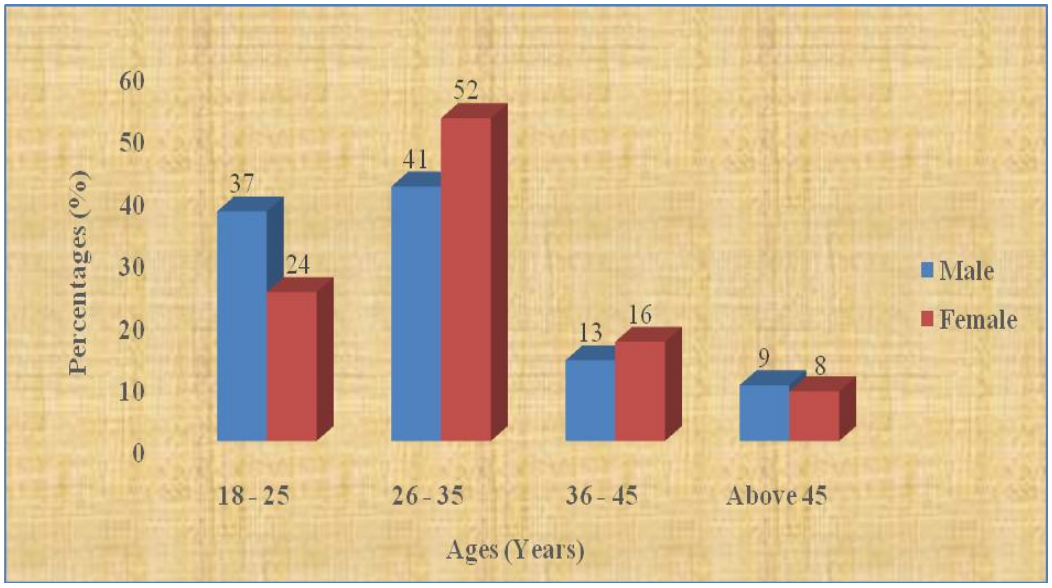


Figure 4.13: Gender and age distribution of KNWWs Staff

4.8.2 Educational Background

All the staff interviewed had a minimum of Secondary and Technical education 70 % which is deemed necessary for the work. Most of them (55 %) had tertiary education comprising a degree and professional training and 75% have Diploma which are mostly technical staffs as shown in Table B2 (Appendix B) and presented in Figure 4. 14.

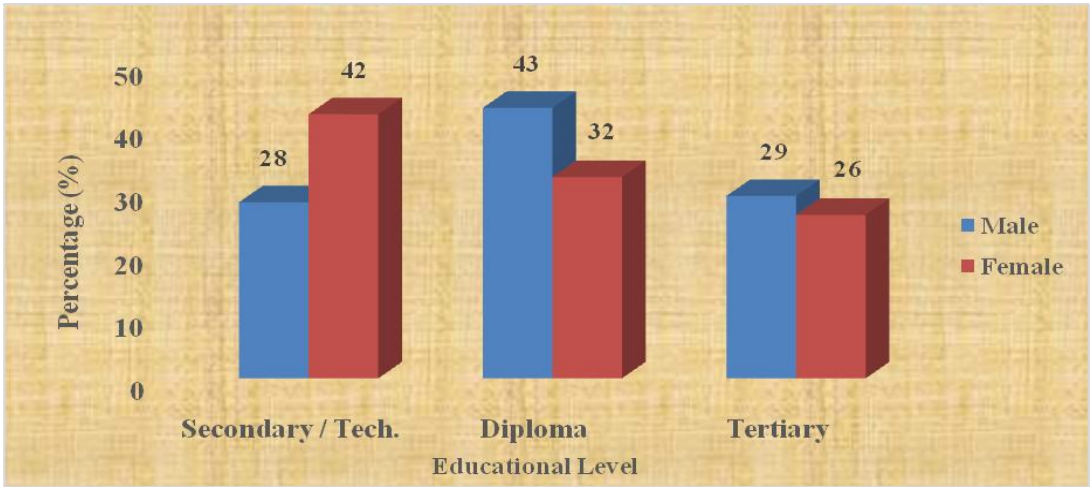


Figure 4.14: Educational Levels of Staff

4.8.3 Effects of Inadequate Water Supply

The respondents were asked to comment on various issues bordering on inadequate water supply and delivery in the Kaduna North Waterworks Communities. These are some analyses of their responses shown in Table 4.3

Water shortages slows down domestic and commercial activities

On whether "water shortages was a problem that slowed down both domestic and commercial activities" , 256 (64 %) out of 400 respondents said it was a problem, 100(25 %) said it was not a problem and 44 (11 %) was indifferent as shown in Table 4.3, that intermittent shortages should not be a cause for worry when one is able to store enough water.

High water charges from water vendors

The Table 4.3 indicates that out of the 400, 286 (72 %) of the respondents did not see it as a problem but a sign that people were willing to pay a little more should the service delivery improve and 114 (28 %) do not know if it was a problem. The KNWWs should take advantage and improve the water service delivery so as to be able to charge realistic tariffs.

Too much time wasted in search of water

Access to water should be as effortless as possible, so when a lot of time is wasted in search of water then it becomes a problem. This is supported by 150 respondents out of 400 with 38 % as severe problem, 240 out of the 400 respondents interviewed said it was a minor problem by 60 % and 10 (2 %) out of the 400 said it was not a problem as shown in Table 4.3. Alternative arrangement for water supply should be made available whenever the problem is anticipated to last for more than a couple of days.

Long queues in fetching water leading to quarrels

People normally for the sake of orderliness would join the queue and wait for their turn to be served. However, due to frustration and impatience when others try to jump the queue because of delays, this often degenerates into quarrels. From the Table 4.3, 120 (30 %) people said it was a severe problem, 200 (50 %) said it was a minor problem while 80 (20 %) did not see it as a problem. More vending points should be opened by KNWWs in partnership with the private sector to forestall such problems.

Risks the lives of children and reason for truancy

Everybody is aware of what time water flows and are obliged to store water for use. However, when water delivery is cut abruptly, leading to a shortage, school children are the most affected since they have to move around in search for water for the household. This is a problem that is acknowledged by 85 % of the respondents that it endangers the lives of children and also a cause for lateness and absenteeism from school. The KNWWs should provide more vending points in areas where there are frequent water shortages.

Risk in using untreated water from streams and wells

Where provision for water and sanitation are inadequate, the diseases that arise from contaminated food, water and hands are among the world's leading causes of premature death and serious illness (UN, 1977). The Table indicates that all the respondents were unanimous in their response that this was a problem which needed to be tackled by ensuring that access to portable clean and safe water was always available to all and sundry.

Table 4.3: Issues about Water supply and delivery

Issues	Severe Problem	%	Minor Problem	%	Not a Problem	%	Don't Know	%
Slows down domestic and commercial activities	-	-	256	**64**	100	**25**	44	**11**
High water charges from water vendors	-	-	-	**-**	286	**72**	114	**28**
Too much time wasted in search of water	150	**38**	240	**60**	10	**2**	-	-
Long queues in fetching water leading to quarrels	120	**30**	200	**50**	80	**20**	-	-
Children risk their lives searching for water	80	**20**	260	**65**	50	**12**	10	**3**
Risk in using untreated water from streams and wells	280	**70**	120	**30**	-	-	-	-

4.8.4 Reasons for Inefficiencies in Water Supply

Perennial effects of the dry harmattan and bush burning

The dry harmattan season which starts in December and extends to March/April in the transitional belt covers the whole of the Northern region. This normally leads to a drastic fall in humidity and scanty rainfall if any and a lot of bush burning which causes many of the rivers and streams to lose so much water invariably affecting water production in the region.

The Table 4.4 indicates that 70 % of respondents acknowledged this as a problem and the KNWWs in collaboration with development partners should intensify education on the effects of bush burning and encourage stakeholders to plant more trees along the river banks to serve as shade and prevent excessive evaporation.

Frequent Pipe Bursts and Leakages

Revenue is a function of price and quantity; hence loss of water through pipe bursts reduces the quantity of water that reaches the customer and invariably revenue. The KNWWs main distribution pipes are old metal pipes that have received little or no replacement since the

construction of the water delivery system. Most of these pipes have seen severe corrosion which bursts frequently and affects the distribution as the system has to be shut down for repairs.

The Table 4.4 indicates that 80 % of the officials thought it was a problem that was affecting revenue generation which had to be given serious attention. Plate 1 and 2 shows some of the pipes burst and leakages.



P**late 1:** Leakage from clear water channel to the drain.



Plate 2: 6'' leaking sluice valve before the aeration tank

Power outages leading to disruption in water flow

From the Table 4.4, 86 out of the 95 (90 %) officials responded that power outage was a problem since it disrupts the constant flow of water leading to shortages and its attendant problems.

Management of Kaduna North Waterworks (KNWWs) should provide a standby generator to power the machines when the power goes out.

Obsolete machines at the head works leading to frequent breakdowns

Technology keeps changing rapidly in search for better efficiency in production. Getting the needed replacement parts for some old machines at the head works has become a problem. They have become more expensive to maintain and a drain on the company's resources.

The Table 4.4 shows that 60 % recognized it as a problem, 32 % said it was not a problem since the head works was not producing at full capacity and 8 % were indifferent. The frequent breakdown leads to non-achievement of production targets. Plate 3 and 4 show the gas chlorination system and its alternative method.

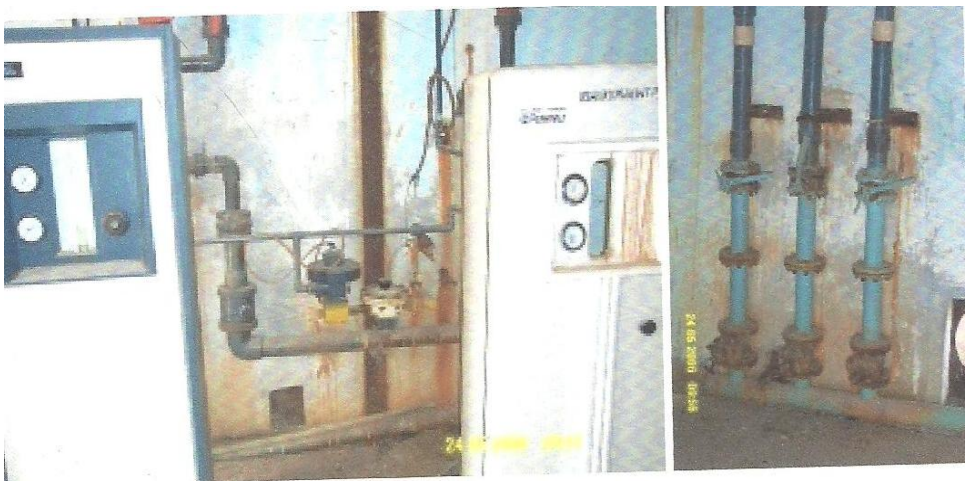


Plate 3: Gas Chlorination System at the chemical building of KNWWs



Plate 4: Chlorination Using Barrel at the clear water tank of KNWWs

Population explosion and unplanned settlements

The rapid increase in the population of the Kaduna North communities has led to a lot of unplanned settlements which are not captured by the KNWWs plans. This has led to illegal connections by consumers especially water vendors to these areas which is a source of loss of revenue to the company.

Table 4.4 indicates that the respondents were unanimous in their decision that this phenomenon was a problem to the Kaduna North Waterworks (KNWWs).

Table 4.4: Reasons for Inefficiencies in water Supply

Issues	Severe problem	%	Minor Problem	%	Not a Problem	%	Don't Know	%
Perennial effects of the harmattan and Bush burning	19	**20**	48	**50**	10	**11**	18	**19**
Frequent pipe bursts and leakages	38	**40**	38	**40**	19	**20**	-	**-**
Power outages leading to disruption in water flow	57	**60**	29	**30**	9	**10**	-	**-**
Obsolete machines at the head works leading to frequent breakdowns	12	**13**	45	**47**	30	**32**	8	**8**
Division of River Kaduna for agricultural purposes	19	**20**	57	**60**	19	**20**	-	**-**
Increase in Population	57	**60**	38	**40**	-	-	-	**-**

4.9 Key Performance Indicators (KPI) for Water Service Delivery

A service performance evaluation metrics (SPEM) was used to adequately appraise the condition of existing schemes and the performance of water supply services. The key Performance areas to be evaluated by SPEM are the operational, financial, institutional and human resources with their respective key performance indicators and key performance objectives as it is presented in the Tables 4.5 – 4.8.

From the SPEM analysis carried out as shown in Table 4.5, KNWW operational capacity is not encouraging as analyzed from the key performance indicator, the maintenance frequency is within three days and one week respectively which indicates lack of maintenance frequency. Maintenance schedule was not properly found, which is one of the main unit in any water treatment plant/waterworks, the maintenance planning shows that the routine maintenance is carried out after the schedule days leading to more damage of components and low production of the operational capacity of the Kaduna North waterworks.

The number of metered and service connection was also not encouraging due to these the capacity utilization is below 50 % from the results and shows that these KNWW operates at half the installed capacity with low service coverage on average and also reduces the stand by capacity of the plants, interruption of the water supply when further break down occur. The duration of water supply from morning, afternoon and evening is between 2 – 8 hrs/d as shown in Table 4.5 and this is due to the volume of water produced is less than the expected volume of water needed for Kaduna North municipalities. Unaccounted water is very high due to the vandalization of pipes, illegal connection, leakage of pipes and

breakage that occur during construction. The operational capacity is 47 % which the overall sustainability indicated a fairly sustained system with higher room for improvement.

Table 4:5: Scoring matrix for Operational capacity

Key Performance Indicator	Key Performance Objective	Frequency
1. Maintenance Frequency	**i.** MTTR fault < 24 hours	0
	ii. MTTR 24 hours	0
	iii. MTTR two days	0
	iv. MTTR three days	2
	v. MTTR one week	1
2. Maintenance Planning	**i.** Monthly routine maintenance established	2
	ii. Routine maintenance carried out one day after the scheduled date.	2
	iii. Routine maintenance carried out two days after the scheduled date.	1
	iv. Routine maintenance carried out one week after the scheduled date.	1
	v. No routine maintenance schedule established	0
3. Number of metered connection	**i.** Above 20,000	0
	ii. 16,000 - 19,000	3
	iii. 11,000 - 15,000	2
	iv. 6,000 -10,000	1
	v. 1,000 - 5, 000	1
4. Number of Service connection	**i.** Above 20,000	0
	ii. 9,000 - 10,000	3
	iii. 7,000 - 8,000	2
	iv. 5,000 - 6,000	1
	v. 1,000 - 4,000	2

MTTR = Minimum Time to Resolve (Maintenance Problem)

Table 4:5: Continued

Key Performance Indicators	Key Performance Objectives	Frequency
5. System Capacity Utilization	**i.** 90 - 100 %	0
	ii. 70 - 89 %	0
	iii. 50 - 69 %	2
	iv. 30 - 49 %	2
	v. 10 - 29 %	1
6. Duration of Supply	**i.** 20 - 24 hr/d	0
	ii. 15 - 19 hr/d	0
	iii. 10 - 14 hr/d	0
	iv. 9 - 13 hr/d	0
	v. 2 - 8 hr/d	4
7. Volume of water Produced (m^3)	**i.** Above 60, 000	0
	ii. 1,000 - 9,900	1
	iii. 40,000 - 59, 000	3
	iv. 10,000 - 19,000	0
	v. 0 - 9,000	0
8. Unaccounted for Water	**i.** 5 – 25 (%)	0
	ii. 26 – 35 (%)	0
	iii. 36 – 45 (%)	2
	iv. 46 – 55 (%)	2
	v.56 – 75 (%)	4
Total		**45**

MTTR = Minimum Time to Resolve (Maintenance Problem)

From Tables 4.6, the financial capacity of KNWW was carried out and analyzed under the following performance indicators, funding, billing, collection efficiency and financial efficiency with respect of their key performance objectives. Funds are not enough to meet the operational needs; they are only available to cater for minor repairs which are not sufficient for operational cost. As the funds are not enough the billing too is also affected which is below the average for billing (Green, 2003), from the result obtained 10 – 29 % is the highest billing that responded which leads to low collection efficiency below 50 % and financial efficiency is within 7 – 10 months. 23 % was analyzed for the financial capacity

evaluation of Kaduna North Waterworks (KNWW) which is not encouraging and need more improvement, because without enough financial capacity, the whole system (KNWW plant) cannot operates effectively.

Table 4:6: Scoring matrix for Financial capacity Evaluation

Key Performance Indicator	Key Performance Objective	Frequency
1. Funding	**i.** Funds were adequate to meet system Upgrades and operating Costs.	-
	ii. Funds adequate only for system upgrades	-
	iii. Funds Only sufficient for operational costs	3
	iv. Fund available to cater only for minor repairs	2
	v. Funds not enough to meet operational needs.	4
2. Billing (%)	**i.** 90 – 100	-
	ii. 70 – 89	-
	iii. 50 – 69	1
	iv. 30 – 49	2
	v. 10 – 29	4
3. Collection Efficiency	**i.** 90 – 100	-
	ii. 70 – 89	-
	iii. 50 – 69	-
	iv. 30 – 49	2
	v. 10 – 29	1
4. Financial Efficiency	**i.** 3 Months	-
	ii. 3 – 6 Months	1
	iii. 7 -10 Months	2
	iv. 10 – 12 Months	-
	v. Above 12 Months	-
Total		**22**

From Table 4.7, the key performance indicators analyzed for the institutional capacity evaluation are capacity building partnership and technical assistance with their key performance objectives. From the analysis, 15 % of the institutional capacity evaluation and the operational staffs are trained below necessary level. The institutional capacity of any organization determine the work force of the organization (KNWW), if the institutional capacity of staffs are below average as shown from the SPEM analysis in Table 4.7 then Kaduna North Waterworks will operates at a low capacity.

Table 4:7: Scoring matrix for Institutional capacity Evaluation

Key Performance Indicator	**Key Performance Objective**	**Frequency**
1. Capacity Building Partnership	**i.** Strong partnership exists between federal, State, the Board and external agency	2
	ii. Strong partnership exists between federal, State and District Utilities.	1
	iii. Partnership exists between State, External agency and District Utilities.	2
	iv. Partnership exists between State District Utilities.	3
	v. No partnership exists	
2.Technical Assistance	**i.** Technical service level agreement exists between State, external agency and Board	2
	ii. Technical service level agreement exists between external agency, Board and District Utilities	1
	iii. Technical service level agreement exists between Board and District Utilities	1
	iv. Technical service level agreement exists between external agency and District Utilities	2
	v. No technical service level agreement exists.	
Total		**14**

Table 4.8 shows the analysis for the human resources capacity evaluation in respect of the following key performance indicators number of staffs/1000 connection, Training and Development, and Customer centric and their respective key performance objectives. The analysis shows that KNWW lack manpower as shown in Table 4.8, 10 -15 persons are the number of staffs/1000 connection and no training/workshop or seminar are arrange for the staffs and to have a training program is very important which improve the development of staffs. The customer centric is very poor. 15 % was evaluated for the human resources capacity which is not encouraging and needed a maximum attention in order to improve the standard of the waterworks.

Table 4:8: Scoring matrix for Human Resources Capacity Evaluation

Key Performance Indicator	Key Performance Objective	Frequency
1. Number of Staff/1000 Connection (Persons)	**i.** 10 – 15	2
	ii. 16 – 21	1
	iii. 22 – 27	0
	iv. 23 -28	0
	v. 29 – 34	0
2. Training and Development	**i.** Staff attend courses quarterly	0
	ii. Staff attend courses twice annually	1
	iii. Staff attend courses once a year	1
	iv. No training/workshop or seminar attended	4
3. Customer Centric	**i.** Excellent	0
	ii. Very Good	0
	iii. Good	1
	iv. Fair	1
	v. Poor	3
Total		**14**

4.9.1 SWOT Analysis

In order to establish the basis for the developing strategies for the performance improvement plan, SWOT analysis of the present situation was carried out to identify the Strength, Weakness, Opportunities and Threats of Kaduna North Water Works (KNWW). The SWOT analysis focused on the operational areas that the management of Kaduna North Water Works considered key in short and medium term. Other operational areas that directly influence the management deemed critical were also analyzed in order to provide a wholistic and fairly comprehensive platform for more coherent formulation/development. The Strengths of the KNWW, their Weaknesses, Opportunities available to the Water Board and the Threats confronting the Water Board are discussed below;

4.9.1.1 Strengths

Raw water

There is abundant raw water all year round of standards requiring only routine treatment process in the rivers that flow through the State available to KNWW. There is enough water to meet the potable water demand of the whole State with Kangimi Reservoir as a supplementary water retaining structure.

Good customer relation

It has been revealed that the people of Kaduna State generally have an easy and friendly attitude towards the boards' commercial staff and that they are ever willing to collect and pay their water bills. KNWW should not relent on regular customer education and enlightenment to sustain this relationship.

Abundant water treatment capacity in KNWW

KNWW alongside the proposed phase 2 treatment plant as well as Kaduna South treatment plant have the capacity to meet the water demand of Kaduna State.

Political will of the State government

The Kaduna State government is ever ready to lend its support to the KNWW through it annual subvention or willingness to guarantee loans from donor agencies.

4.9.1.2 Weaknesses

Inadequate power supply from PHCN

Power supply from PHCN to the water work is epileptic, and at most times the supply comes either with low voltage or with a surge, leading to damages to electrical equipment installed for efficient operation of the treatment plant, and in some cases makes it impossible to operate the plant. The effect of this should be minimised through the construction of dedicated 33KV power supply line to the plant and installing power conditioning equipment such as balancing/stabilizing transformer, electro-flow and power perfector.

High cost of diesel

As the power supply from the main power provider PHCN is unreliable and uncertain, most of the water schemes have to depend on diesel run generators. The single largest cost in the operation of a water supply industry is diesel/power. This increases the cost of treating water which becomes unbearable for the government.

Breakdown of some water system

Some of the water systems in all the areas under this study had broken down. Most of them need replacement.

Inadequate distribution network

The existing water distribution capacity in Kaduna is grossly inadequate as a result of the rapid development of satellite towns where the distribution network is inadequate.

4.9.1.3 Opportunities

International donor agencies

Many donor agencies have been responding to the needs of KNWW and are ever willing to come in when the need arises. With prudent application and management of fund, there is no reason for the board not achieving its mandate of meeting the potable water demand of the whole state with assistance of these agencies.

Abundant customers

Customers abound in Kaduna and its environs, waiting to be served with potable water. Where there are abundant treatment capacities efforts should be intensified in extension and densification of the distribution systems, and where treatment capacities are lacking, provisions should be made for adequate capacities as well as matching distribution systems.

On-the job training

During the construction of the various components of the water systems a number of the Water Boards staff were attached to the contractors and supervising consultants for on-the job training. Only limited number were involved and in most cases the time allowed and the crowded schedule of the trainers did not allow for proper training on the assigned.

Use of local industries

Many waterworks plants and equipments are broken down and waiting for funds for importation of spare parts. Opportunities abound for manufacture of these spares in Nigeria using other lathe-works and foundries to be

4.9.1.4 Threats

Civil service salaries

It is understand that the KNWW still pays civil service salaries to its staff. This would definitely not encourage hard work and dedication expected from the staff of a profit-oriented company and can even lead to loss of trained and experienced staff to other lucrative jobs.

Political interference

Highgly influential citizens often interfere with the technical processes in the procurements of pumps, equipments and contractual proceeds which are supposed to be professionally handled in terms of specifications, and the bidding process, thereby creating loopholes in the structure of the waterworks.

Illegal connections

Customers whose houses are around the mains of the KNWW pipe network tend to illegally connect to the mains unprofessionally which leads to mains leakages and water losses and most regrettably serving as an opening for recontamination by pollutants.

4.10 Need Assessment of Kaduna North Waterworks (KNWW)

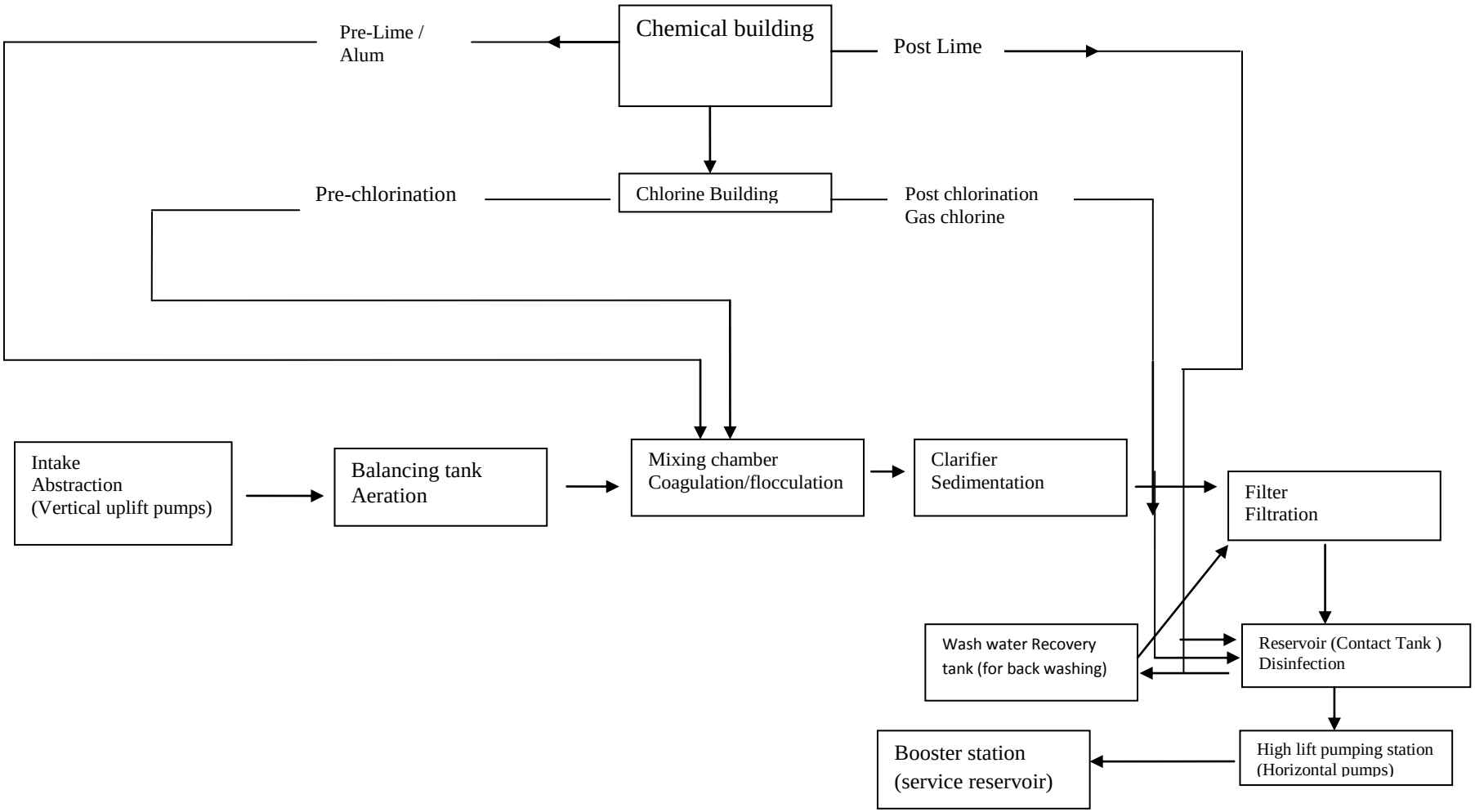


Figure 4.15: Steps and Processes of Water Treatment at Malali Water Works

4.10.1 Intake

A weir constructed across Kaduna River impounds the flow of the river. The intake consist of the intake chamber with intake gates and a wet well with pump house on top. The original intake design has been changed by dismantling an intake cleaning device which removes plants and rubbish from the intake chamber. The intake pump house was constructed to accommodate seven (7) pumps. Originally three pumps, with two running one on standby mode were to pump raw water to the pre-settling tanks.

The current operational mode is three pumps pumping to the pre-settling tanks and one pumping to the balancing tank. One of the three pumps that is supposed to pump to the balancing tank and the pre-settling tank was under still under repairs.

Pumps to the pre-settling tank of three (3) pieces each of discharge 1051m^3/h at 15.6m head and driven by a 415V/64kW inductor motor. The pumps to the balancing tank of one pieces with a discharge of 456m^3/h at 25.7m driven by 415V/51kW induction motor and two pieces of discharge 1800m^3/h at head 28m driven by 415V/200kW slip ring motor.

The intake of the Kaduna North Waterworks (KNWW) is in operational condition, but there are problems with heavy silt as well as with plants and debris in the intake chamber. Plate 5 and 6 show the intake chamber. Pumps seem to deliver below design capacity, instrumentation and controls are only partly in working condition. Repairs are nearly everyday occurrences. Plants, rubbish and debris float into the intake chamber and sucked to the pumps, where it finally blocks the pump strainer. The result is a running pump delivering far below design capacity and using far more energy than for the production needed. One out of the three motors for the dosing pumps is under repair; a second was for some times under repairs as well. The motors have been reportedly rewound severed times.

In order to avoid high frequency repairs, these motors should be replaced. The mixing of the alum solution is done using blowers; both blowers are still in running condition but should be replaced for effective mixing because they are slow in operation. The pressure reducing value in the clear water supply line is not working. The pipe work within the building is leaking on several points and needs repairs.

The following summarizes the findings after preliminary investigation of the intake unit of KNWW.

i. The reservoir is heavily silted.
ii. Level control system not functional
iii. Gate valves and non-return valves, the pump suction gate valves are difficult to operate and non-return valves are leaking profusely.
iv. Flushing to de-silt is in progress by backwashing to wash accumulated silt downstream.
v. The raw water pumps the rotating part of pump is worn out.
vi. Penstock gate and inlet screen, main intake gates cannot be operated due to silt deposition.
vii. The Alum dosing equipment should be overhauled, thus including mixing tanks and all pipe work.

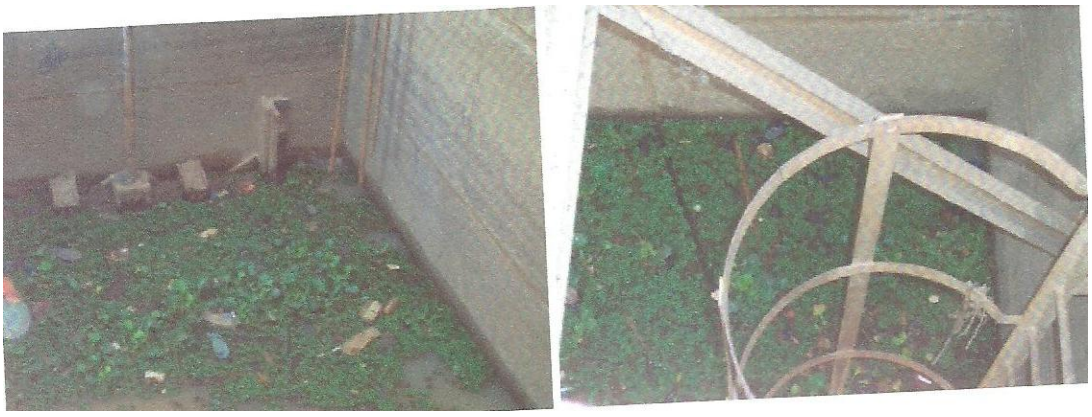


Plate 5: Plants and debris in the intake chamber of Kaduna North Waterworks

4.10.2 Pre-Settling Tank

In order to allow mixing of chemicals a static mixing chamber is placed before the pre-settling tanks. The pre-settling tanks are three in number, two bigger one and one valve are generally in working condition but are in need of service and minor repairs because the flowing metering system is not operational, pump test could not be carried out. The instrumentation is only partly working. Two of the four ampere meters connected to a pump operating are not working; some indicator lamps are not working or show wrong indications. To none of the four pumps, running at a time of assessment was a delivery pressure gauge in working condition attached. Water is trapped from the Kamazo pump line for cooling of intake pumps.

Because there is no drain system installed, maintenance and repairs is extended in time well the needs to be clean or drained.

The raw water pipelines to the balancing chamber and to the pre-setting tank cannot be washed out properly. It is observe that the pipes are full of silt, which lead to change pump head, loss of delivery and energy losses. The plates below show the pre settling tanks.



Plate 6: Pre-settling tank inflow of Kaduna North Waterworks

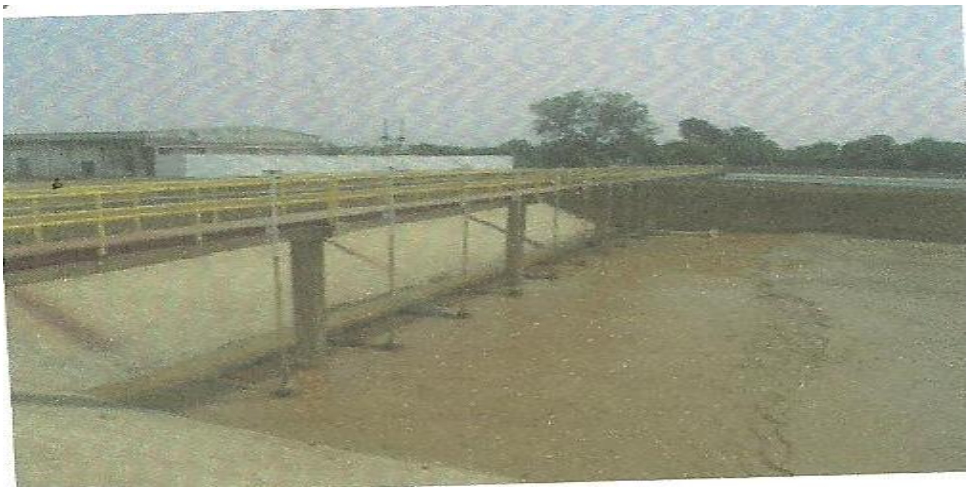


Plate 7: Pre-settling tank disludging of Kaduna North Waterworks

4.10.3 Chemical Dosing for Pre-settling

The chemical dosing for the pre-settling consists of Alum, polymer and lime dosing. Currently only the Alum dosing equipment is used. The main control board has been vandalized and the vandalized equipment needs to be replaced.

As a result of the vandalized equipment and the unavailability of chemicals, especially polymer, the lime and the polymer dosing have never been operated. Nevertheless both systems are in good condition and it is assumed would work if needed.

The Alum dosing system consists of two mixing chamber, two blowers, and three alum dosing pumps. The system is operational but in poor condition. The system is in running condition, problems occurring are mainly caused by clogging drain lines. One of the inlet values is difficult to operate. There are reportedly structural problems with the tank. The inlets for the chemicals are below the water surface and have reportedly clogging and silt problems leading to unequal addition of chemicals.



Plate 8: Blower of Kaduna North Waterworks



Plate 9: Alum dosing pump of Kaduna North Waterworks



Plate 10: Alum mixing tank of Kaduna North Waterworks

4.10.4 Pre-Settling Pump Station

Four pumps, each 950 m^3/h at 9.75 m, pumping to the filter are installed in the pre-settling pump station. Pumps are started with a star delta starting system.

All valves are operational condition but need servicing. All four pumps are in operational condition but only two pumps can be run because of problems with the MCC. The changeover board Power Holding Company of Nigeria (PHCN) to generator needs to be repaired.

4.10.5 Balancing Tanks

Three (3) out of the six (6) pumps at the inlet are pumping to the balancing tank. Solids settle partly here and then can be drained through a de-sludging pipe work. Due to a faulty inlet flow regulation to the sedimentation tanks, water is simply flowing through the balancing tank as shown in plate 11. It has been observed that the intake is full of sludge and it has been reported that the de-sludging system blocks regularly.



Plate 11: Balancing tank full of sludge of Kaduna North Waterworks

4.10.6 Chemical Dosing before Sedimentation Tanks

The mixing of the chemical take places in two separate buildings one building is used for preparation of polymer and Alum, the other one for the preparation of lime solution. The polymer dosing consists of two complete units and use never used.

The Alum dosing is operational and consists of three mixing tanks, two blowers and two dosing pumps. The mixing of the alum solution is done by blowers. Only one blower is operational, the other under repairs. Also only one alum pump is operational and the other one under repair.

The pipe work is leaking on several places and needs serious attention. As stated above, the lime mixing covers for the flash mixing chamber before the sedimentation tanks as well as for the injection into the clear water reservoir. The lime system is in operational condition and needs beside regular maintenance no major repair work.

4.10.7 Sedimentation Tank

Fourteen (14) hopper bottomed upward flow sedimentation tanks have been constructed. The inlet flow regulation system is not working. Two of the inlet valves do not work. There

are problems with the de-sludging and bleeding process, which need to be investigated further, the systems tends to block. Staffs tries to avoid the blockage problem with constant de-sludging by leaving the de-sludging gate valves partly open. Pipe work including valves in general need to be overhauled. The plates 12 and 13 below show the sedimentation tank.

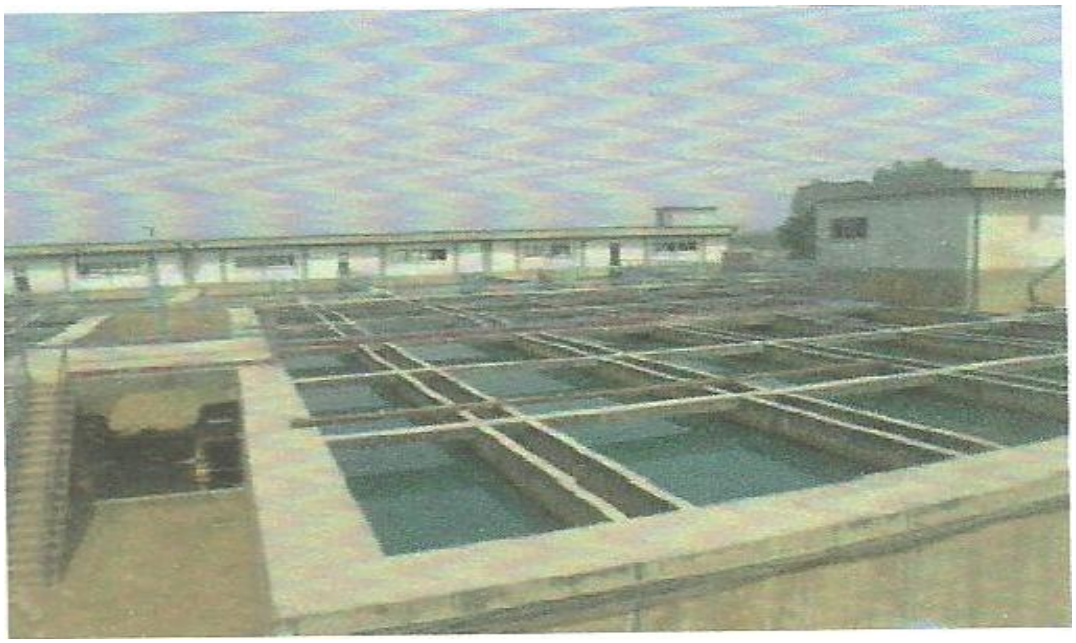


Plate 12: Sedimentation and puslator building of Kaduna North Waterworks



Plate 13: Desludging the sedimentation tank of Kaduna North Waterworks

4.10.8 Filter

Twelve (12) rapid sand filters were constructed. The pipe work is in poor condition and partly corroded valves are in very poor condition, some not working and some difficult to operate. Penstock are not working, or not closing correctly leading to continuous drainage of water from the filter surface to the drain.

Not functioning and not foreseen controls lead to very high water levels in the filter. The backwash system is in working condition, but due to the poor valve condition the backwashing is difficult to carry out. Backwashing is controlled by a semi-automatic system using pneumatic valve control. The backwash system consist of two backwash pumps (Alsthom), delivering 1,210 m^3/hr at 6m and two air compressors (Atlas Copco) of 4,835 m^3/hr capacity. one of the air scour blower is not working due to a defective starter system. Two compressors deliver air for the operation of air-controlled valves. The pneumatic pipe work including the valves is working but needs overhaul. The filters itself have repeatedly occurring problems like clogging and a partly collapsing filter floor assembly. Since the controls are not functioning, the operation depends entirely on the manual operation by the operator, who is also responsible for operation of the balancing tank, sedimentation tank and the filters. Since the operation of this entire plant element is entirely manual and therefore needs continuously monitoring and operation, the operator seems to be simply overloaded with duties.The filter operation is currently not at an optimal level. The plates below show the filter medium and its current condition.



Plate 14: Filter bed of Kaduna North Waterworks

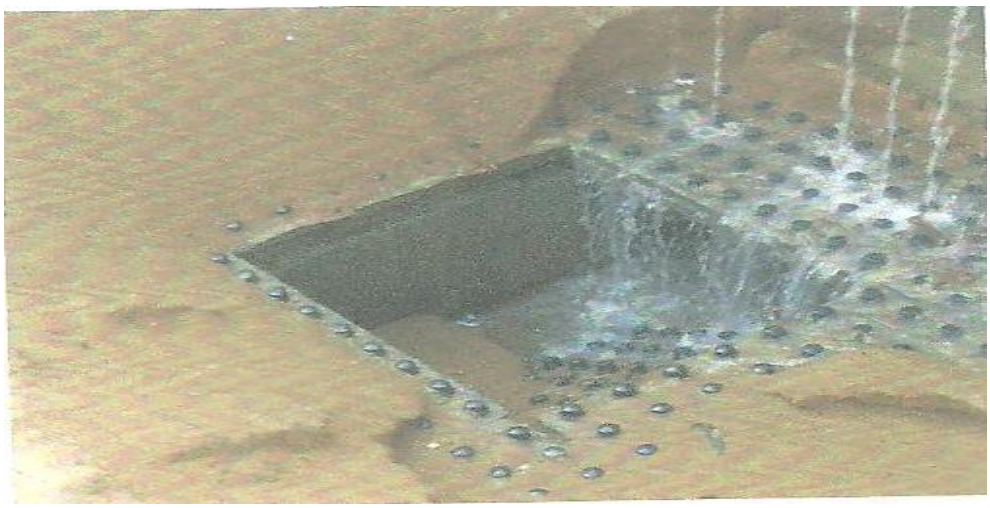


Plate 15: Collapsed Filter bed

4.10.9 Chemical Dosing for Reservoir (Contact and Clear water Tank)

Lime and chlorine are added into the reservoir. The condition of the lime mixing equipment is without major problems. The chlorine dosing was originally done by chlorine gas but has been changed to HTH. The chlorine gas system is in poor condition and needs complete rehabilitation if put back to operation. If the decision would be to re-commission the system, it would have to be overhauled or replaced first.

One out of the three gas chlorinators was working, the pipe work needs replacement. The both chlorine motive pumps are not working. The HTH dosing is still done using a barrel as a temporary solution.

4.10.10 Backwash Tank

The backwash tank is an elevated steel tank of 400 m^3 capacity. It is charged by a branch from the pipeline leading to the state house. The high level control of the tank, using a float valve is not working. To overcome the problem an overflow back to the reservoir should be installed. The high level control has to be repaired to avoid water pumped in a circle and energy being wasted.



Plate 16: Backwashing of the filter

4.10.11 High Lift Pump Station

The high lift pump station is equipped with three pumps which are supposed to pump to the state house. The pump station is not operated at the moment. Only one of the three pumps is in working condition. Motors are started by autotransformers. One module of the MCC has newly been installed. The pump station is not operated due to lack of water at the clear water reservoir.

The pumps are worn out, there are major problems with the pump plinth, pump motors frames and alignment which leads to high vibrations and early wear of the equipment. Two out of the four pumps to Lagard hall do not work. Gate valves and non-return valves are in poor condition and partly not working. There is no pressure gauge in working condition.

4.10.12 Clarifiers

Four (4) Clarifiers, (pulsator type of clarifiers) were constructed, including an automatic de-settling system. The vacuum pumps for the pulsator are in working condition but are not operated due to defect starter systems. Therefore there is no pulsing of the clarifier. Since the pulsator is not working the sludge blanket is not kept in expansion. This leads to a situation of uneven distribution, poor flocculation, sludge deposits on the bottom tank and a not working de-sludging system. The sludge deposits consequently have to be removed by hand involving an enormous amount of manpower and water.

The sludge plates of the clarifiers have been removed and a large number of inlet pipes are broken or have been removed. This leads to a situation where the system is unable to work in any efficient way. There seem to be need of training in the knowledge of operational principles of the system.

The automatic de-sludging system is not working. An operational system of permanent leading to high water losses.

4.11 Booster Stations

4.11.1 State House Booster Station

The State House Booster Station consists of old pump station, new pump station, generator building and storage reservoir. There is no inflow control to the reservoir. The mechanical level indicator is not working. The old pump station of;

1. One state House pumps which is dedicated for supply to the State House through a 100 mm diameter pipeline.
2. Two NDA pumps, one duty and one standby each delivering 550 m^3/h at 30 m. NDA pumps deliver directly to the distribution , through a 200 mm diameter pipeline, and supply to the state House, through the 100 mm diameter pipeline by operation of valve.

Running hours of the pump station as 27th of October to 27th November, 2015;

The pump P1, pumping to the state house, runs for 72 hours.

The pump P2, pumping to the NDA, runs for 49 hours.

The pump P3, pumping to the NDA, runs for 42 hours.

The new pump station consists of;

1. Two NDA/Mando Pumps (one duty and one standby) each delivering 504 m^3/h at 55 m. the NDA/Mando pumps serve the NDA and Mando service reservoirs through separate transmission mains by operation of valves.
2. Two Airport Pumps (on duty and one on standby) each delivering 475m^3/h, at 40 m.

Running hours of pumps within the time from 27th of October to 27th November, 2015;

The pump P1, pumping to the Air Port, runs for 95 hours.

The pump P2, pumping to the Air Port, runs for 26 hours.

The pump P3, pumping to the NDA/Mando, runs for 156 hours.

The pump P4, pumping to the NDA/Mando, was not in operation.

The supply from the Kaduna North plant has not been sufficient. PHCN power supply is assessed intermittently and a low voltage has been reported, leading to a situation where staff has bypassed the motor protection. A standby generator was provided for the booster station to overcome poor PHCN power supply. The generator is installed in the pump station building, leading to situation where, when the generator is running, the allowed noise level in the pump operation room seems to be overstepped. This also would make it difficult for the operator to detect any unusual pump sound.

4.11.2 Lagard Hall Booster Station

The Lagard hall booster station consists of old pump station, new pump station, generator building and four reservoirs.

The old pump station has been abandoned, the roof slab is partly collapsed; the adjacent office and store building is similarly abandoned.

The new pump station consists of;

1. Three pumps (two duties and one standby) each delivering 378 m^3 at 46 m.
2. The pumps deliver to the elevated steel tank located at the booster station.
3. The pumps and pipework are old and due for replacement.

Running hours of pumps within the time of assessable from 27th of October to 27th November, 2015:

Pump P1 runs for 341 hours means about 11 hrs per day.

Pump P2 runs for 403 hours means about 13 hrs per day.

Pumps are started with star delta starting systems. The MCC is old and poor condition. Pump Motors are reportedly in continuous burned – rewound cycle. At the time of assessment two of the three motors had been burned and were given for rewinding. The original change over switch PHCN to Generator has been burned, the replacement has not been installed properly. Power outages were in the last year in average 45 hours/months.

4.11.3 Tudun Wada Booster Station

A gravity pipeline feeds the booster pump station from the storage reservoirs at Tudun Wada Hill. The booster station delivers treated water to Rigasa service reservoir through a 450 mm diameter transmission main. The gravity pipeline is a 400 mm diameter main connected to the booster station with provision for a bye – pass for direct supply to the distribution when the booster station is not operated.

Pumps are operational, but several problems like worn out bearings and different delivery capacity indicated that the pumps are due for overhaul. Valves are not working. The flow meters are not working. To overcome constant phase switching by PHCN, an arrangement has been made having each of the pumps connected differently, so the pumps can be chosen which is running in the right direction.

The construction of a generator house has been finished; the installation of a generator is expected. The operation of the booster station is limited due to power supply problems. The pump station building is presently having two pumps installed with provisional space for future pump installations.

Running hours of pumps within the time from 27th of October to 27th November, 2015

The pump P1 runs for 279 hrs, means about 9 hrs per day.

The pump P2 runs for 372 hrs means about 12 hrs per day.

4.11.4 Ungwan Muazu Booster Station

The Ungwan Muazu booster station consists of pump station and one ground reservoir and one elevated tank. The ground reservoir is reportedly sometimes overflowing at night. Original provision consists of two pumps- duty and standby, but there is presently only one pump, delivering 150 m^3/h at 42m, installed in the booster station. The pump at Ungwan Muazu station has, within the time of operation from 27th of October to 27th November, 2015, run for 403 hrs, means 13 hrs per day. Due to the inter-links in the network there is always water in the area, even if the booster station is not operated. The booster station and the reservoirs are in very poor condition.

4.12 Reservoirs

For condition of the reservoirs is shown in Table 4.9 below. In generally reservoirs, valve chambers and valves are in poor condition. Level indications and flow metering is not available or not working. A negative impact has the tapping of the delivery pipelines to the reservoirs. Some of the reservoirs are not reached by sufficient water anymore. Inlet controls using a regulating valve and a flow switch to control the pumps depending on the reservoir level cannot be used anymore. It also affects the pumps, which are not running at the designed operation point.

Table 4.9: Mechanical Condition Assessment for Reservoirs.

Locations	Size (M^3)	Inlet Control	Inlet Flow metering	Level indication	valve chamber	Valve and pipework	Reservoir Condition	Out Flow Metering	Other
Airport	2,500	Not Installed	Not Installed	NOP		OP/Poor	Poor	Not Available	
NDA	4,800	Not Installed	Not Installed	NOP		OP/Poor	Ok		
Lagard Hall Old	4,500	Not Installed	Not Installed	NOP		OP/Poor		Not Available	Access Ladder Corroded
Lagard Hall New	12700	Not Installed	Not Installed	Not Suitable	Poor	OP/Poor	Poor	Not Available	Access Ladder Corroded
Mando	2,500	Not Installed	NOP	NOP		OP/Poor	Ok		Safety Light
State House Kawo	91000	Not Installed	NOP	NOP	Poor	OP/Poor			Access Ladder Corroded
Tudun Wada	2000	NOP	Not Installed	Missing	Damaged	OP/Poor			Structural Critical
Rigasa	6750/ 11000	NOP		OP		OP/Poor			Access Ladder Corroded
Ungwan Muazu	2500	NOP	Not Installed	Missing	Damaged	OP/Poor	Leaking		Structural Critical

The reservoir was also assessed to know the capacity it was design for, types, date of commissioned and the present working conditions as presented in Table 4.10 below.

Table 4.10: Existing Water Reservoirs in Kaduna North

S/No.	Location	Type of Reservoir	Capacity (m^3)	Date Commissioned	Present Status
1	**Airport**	Braithwaite	2,500	1978	Not Functional
2	**NDA**	Braithwaite	4,800	1975	Functional
3	**Lagard Hall Old**	Braithwaite	4,500	1971	Functional
	Lagard Hall New	Braithwaite	12,700	1971	Functional
4	**Mando**	Concrete	2,500	1984	Functional
5	**State House Kawo**	Concrete	9,100	1971	Functional
6	**Tudun Wada**	Concrete	12,300	1987	Functional
7	**Rigasa**	Concrete	11,000	1986	Functional
8	**Ungwan Muazu**	Braithwaite	2,500	1985	Functional

Source: Field Survey; 2015

4.13 Sources of Electricity

Main source of Electricity is the Power Holding Company of Nigeria (PHCN). PHCN supplies power to all water works and booster stations. There seem to be major problems with the PHCN power supplies. Especially the problems of alleged phase switching and under and voltage, since leading to motor and pump damages are serious as shown in table 4.11 and 12 below. This problems need to be investigated further and if proven reported correct be taken up with PHCN Management or even at higher level.

Table 4.11: Electricity demand as shown in Kaduna North Old Plant.

S/No	Item Description	Location	Pumping to	Installed Power (kW)	
				Stand by	Duty
1	Raw water Pump 1	Intake	Pre-settling		64,00
2	Raw water Pump 2		Pre-settling		64,00
3	Raw water Pump 3		Pre-settling	64,00	
4	Raw water Pump 4		Balance Tank		20,00
5	Raw water Pump 5		Balance Tank	20,00	
6	Raw water Pump 6		Balance Tank		51,00
7	Transfer Pump 1	Pre-settling Pump house	Mixing Chamber		36,00
8	Transfer Pump 2	Pre-settling Pump house	Mixing Chamber		36,00
9	Transfer Pump 3	Pre-settling Pump house	Mixing Chamber	36,00	
10	Transfer Pump 4	Pre-settling Pump house	Mixing Chamber	36,00	
11	High Lift Pump 1	Old Pump house	State House		425,00
12	High Lift Pump 2	Old Pump house	State House	425,00	
13	High Lift Pump 3	Old Pump house	State House		425,00
14	High Lift Pump 1	Old/New Pump house	State House		150,00
15	High Lift Pump 2	Old/New Pump house	State House	150,00	
16	High Lift Pump 3	Old/New Pump house	Lagard		545,00
17	High Lift Pump 4	Old/New Pump house	Lagard	545,00	
18	High Lift Pump 5	Old/New Pump house	Lagard		545,00
19	High Lift Pump 6	Old/New Pump house	Lagard	545,00	
20	Air Scour Blower 1	Old Pump house	Filters		220,00
21	Air Scour Blower 2	Old Pump house	Filters	220,00	
22	Air Blower (Alum)	Pre-settling Chemical			11,00
23	Air Blower (Alum)	Chemical Room		11,00	
24	Dosing Pump (Alum) 1	Pre-settling Chemical	Pre-settling Tank		0,37

Table 4.11: Continued

25	Dosing Pump (Alum) 2	Pre-settling Chemical	Pre-settling Tank		0,37
26	Dosing Pump (Alum) 3	Pre-settling Chemical	Pre-settling Tank	0,37	
27	Dosing Pump (Lime) 1	Pre-settling Chemical	Pre-settling Tank		1,1
28	Dosing Pump (Lime) 2	Pre-settling Chemical	Pre-settling Tank	1,1	
29	Dosing Pump (Poly) 1	Pre-settling Chemical	Pre-settling Tank		0,75
30	Dosing Pump (Poly) 2	Pre-settling Chemical	Pre-settling Tank		0,75
31	Air Blower (Alum)	Pre-settling Chemical		1,1	
32	Air Blower (Alum)	Chemical Room			1,1
33	Mixer (Lime) 1 and 2	Pre-settling Chemical		0,18	0,18
34	Mixer (Poly) 1 and 2	Pre-settling Chemical			1,1
35	Dosing Pump (Alum) 1	Chemical Room	Mixing Chamber		0,55
36	Dosing Pump (Alum) 2	Chemical Room	Mixing Chamber	0,55	
37	Dosing Pump (Poly) 1	Chemical Room	Mixing Chamber		0,55
38	Dosing Pump (Poly) 2	Chemical Room	Mixing Chamber	0,55	
39	Dosing Pump (Lime) 1	Chemical Room	Mixing Chamber		1,10
40	Dosing Pump (Lime) 2	Chemical Room	Mixing Chamber	1,1	
41	Dosing Pump (Lime) 3	Chemical Room	Mixing Chamber		1,10
42	Dosing Pump (Lime) 4	Chemical Room	Mixing Chamber	1,1	
43	Mixer (Lime) 1-pre	Chemical Room			
44	Mixer (Lime) 2-pre	Chemical Room			
45	Mixer (Lime) 3-Post	Chemical Room			
46	Mixer (Lime) 4-Post	Chemical Room			
47	Motive Pump 1 and 2	Chorine room			
48	Light/other Equipment	Old			
	Total Installed Power			**2053**	**2630**

Table 4.12: Electricity demand as shown in Kaduna North New Plant.

S/No	Item Description	Location	Pumping to	Installed Power (kW)	
				Stand by	Duty
1	Raw Water Pump 1	Intake	Mixer Chamber		250,00
2	Raw Water Pump 2	Intake	Mixer Chamber	250,00	
3	Raw Water Pump 3	Intake	Mixer Chamber		150,00
4	Raw Water Pump 4	Intake	Mixer Chamber	150,00	
5	Raw Water Pump 5	Intake	Mixer Chamber		150,00
6	Raw Water Pump 6	Intake	Mixer Chamber	150,00	
7	High lift Pump 1	Pump house	Kamazo		715,00
8	High lift Pump 2	Pump house	Kamazo		715,00
9	High lift Pump 3	Pump house	Kamazo	715,00	
10	High lift Pump 4	Pump house	Kamazo	715,00	
11	High lift Pump 5	Pump house	Tundu Wada		200,00
12	High lift Pump 6	Pump house	Tundu Wada		200,00
13	High lift Pump 7	Pump house	Tundu Wada	200,00	
14	Backwash Pump 1	Filter Building	Backwash Tank		30,00
15	Backwash Pump 2	Filter Building	Backwash Tank	30,00	
16	Motive Pump 1	Filter Building	Chlorinatior		11,00
17	Motive Pump 2	Filter Building	Chlorinatior	11,00	
18	Sludge Pump 1 and 2	Compound	Sludge Thickener	4,40	4,40
19	Pulsator Blower 1	Filter Building	Suction Chamber		15,00
20	Pulsator Blower 2	Filter Building	Suction Chamber	15,00	
21	Air Scour Blower 1	Filter Building	Filters		68,00
22	Air Scour Blower 2	Filter Building	Filters	68,00	
23	Air Compressor	Filter Building	Pneumatic Valves		15,00
24	Air Compressor	Filter Building	Pneumatic Valves	15,00	
25	Mixer (Alum) 1	Chemical Room			5,50
26	Mixer (Alum) 2	Chemical Room		5,50	
27	Dosing Pump (Alum) 1	Chemical Room			3,00

Table 4.12: Continued

28	Dosing Pump (Alum) 2	Chemical Room		3,00	
29	Mixer (Lime) 1	Chemical Room			3,00
30	Mixer (Lime) 2	Chemical Room		3,00	
31	Dosing Pump (Lime) 1	Chemical Room			0,75
32	Dosing Pump (Lime) 2	Chemical Room			0,75
33	Dosing Pump (Lime) 3	Chemical Room		0,75	
34	Dosing Pump (Lime) 4	Chemical Room		0,75	
35	Mixer (Poly) 1 and 2	Chemical Room			1,10
36	Dosing Pump (Poly) 2	Chemical Room		0,55	
37	Mixer (Poly) 1 and 2	Chemical Room		1,10	
38	Dosing Pump (Poly) 2	Chemical Room	Mixer Chamber	0,55	
39	Light/other Equipment	New Plant			30,00
	Total Installed Power for New Kaduna North			**2340**	**2570**

4.13.1 Kaduna North Waterworks Plant

The Kaduna North plant is PHCN power supplied by two number step-down transformers (1D + 1 SB), 10 MVA, 33/11 kV. The distribution is then through a local grid of 11kV, both for the Old and New Schemes with individual step-down transformers of 11/3.3 kV and 11/0.415 kV. The HT switchgear at Kaduna North is in good condition. However, the HT distribution board at the New Scheme is created a lot of problems and might be considered to be placed.

Two (2) generators in the Kaduna North Waterworks back up PHCN power supply: one Blackstone generator, 2700 kVA, 3.3 kV for some of the high lift pumps in the old and in the new scheme and one Caterpillar generator, 1,000 kVA, 415V for some intake pumps and the pre-settling pump house. The Blackstone generator that supply power to

the high lift pumps needs total overhaul and another one should be added if possible for effective supply of power to the high lift pump.

The fact that existing generators at the water works are not operated for the most of the power failure times, reinforces of backing up for PHCN is needed. Some of the booster stations are facing more power cuts than the treatment works and backup power is more necessary as in the water works.

As stated above, the biggest waste of energy is pumping water, which is unaccounted for or pumped to waste. Therefore the detection of leaks, of illegal connections, manipulated water meter etc. is absolute essential. The Kaduna North Waterworks plant is assumed to have high water losses already within the plant. Resolving the problem of the internal water losses will lead to reduction of pumping needs at the intake and therefore high saving cost on one hand and, because more water can be delivered to the public, to higher revenue at the other hand.

Energy could even be saved by eliminating the fluctuations in operations, it is recommended to develop an operational concept and pump as evenly as possible, and therefore it would be necessary to avail standby capacity.

4.14 Distribution Network

Several shortcomings of the distribution system included intermittent supplies, frequently assess bursts, inadequate primary and secondary reticulation, suspected large amount of water losses through leakages and illegal connections, inadequate staff to operate, maintain and police the system, vandalism, lack of updated working drawings and operational documentation, inadequate pipe protection and low water pressures in the distribution system.

A real problem what could not be assessed until now and its importance, extent and overall effect on the booster stations and reservoirs and so to the general supply situation of the population are the already existing connections to the mains.

4.15 Population Forecast and Water demand

4.15.1 Population

It is difficult to estimate population growth due to economic and social factors involved. The forecast of the population of Kaduna was estimated with Kaduna State population census estimates of National Population Commission of 1991 and 2006 using both Arithmetic and geometric methods. The average of the forecasted population in 2015 and 2025 are 1,170,153 and 1,260,346 respectively. Table 4.13 shows the population forecast.

Table 4.13: Population forecast

Year	Methods	Population
1991		993,623
2006		1081,254
2015	Arithmetic Method	1,166,451
2015	Geometric Method	1,173,854
Average		**1,170,153**
2025	Arithmetic Method	1,256,830
2025	Geometric Method	1,263,862
Average		**1,260,346**

4.15.2 Water demand

With the forecasted population of Kaduna, the water demands for the year 2015 as well as 2025 were projected to be 251,582,895 l/d and 270,974,390 l/d respectively without leakage losses. With a possibly losses of 15 %, the demand for the 2015 and 2025 are 289,320,329 l/d and 311,620,549 l/d respectively. This was arrived at by multiplying the population by the water requirement l/p/d. Table 4.14 and 4.15 show the water

demand for 2015 and 2025 respectively. The need to project the water demand of Kaduna was necessitated on the increased sprouting of satellite towns and other economic activities in the state. These sprouting satellite towns are attributed with corresponding increase in the water demand as a result of increasing population, commercial centres and institutions e.t.c, but KNWW treatment capacity does not increase, rather it is reducing due to dilapidation and depreciation over time of its water treatment facilities. As at present, the combined water treatment capacity of KSWW is 135 Ml/d, which is less than the demand and far from the initial installed capacity of 291 Ml/d.

Table 4.14: Water demand for the year 2015

Category	**Water Requirement l/p/d**	**Water Demand l/d for 2015**
Domestic	120	140,418,360
Public Utilities	15	17,552,295
Commercial centre	30	35,104,590
Institutional	15	17,552,295
Fire	35	40,955,355
Total demand		**251,582,895**

Table 4.15: Water demand for the year 2025

Category	**Water Requirement l/p/d**	**Water Demand l/d for 2025**
Domestic	120	151,241,520
Public Utilities	15	18,905,190
Commercial centre	30	37,810,380
Institutional	15	18,905,190
Fire	35	44,112,110
Total demand		**270,974,390**

4.16 Water Quality Parameters- Seasonal Analysis

4.16.1 Physical Parameters of KNWW (Water during the Wet Season)

4.16.1.1 Colour

The colour of the KNWW sampled water through its treatment tanks from the raw water tank to the contact tank are presented in Table 4.16. The average values through the treatment processes and operations showed decrease in the colouration of the water except (BSWT and BFWT) in the faulty operation units where agitation of the suspended solids due to bad sedimentation and filtration bed, lead to increase water colour which affects the efficiency of the treatment plant mostly during the wet season. The average colour of the treated water is 10.5 unit which shows significant decrease when compared to the intake, raw water colour with an average 70.875 unit. The average colour of the treated water is within the threshold value of Nigeria standard for drinking water quality, 2007 and WHO drinking water standard, 1993.

Table 4.16: The colour (Unit) of water through the different units in KNWW treatment plant

Sampling Dates	RWT	AWT	CWT	GSWT	BSWT	GFWT	BFWT	CT/TW	WHO 2007	NIG 1993
04/08/2015	65	65	60	5	10	5	5	10		
11/08/2015	70	70	70	10	15	10	10	15		
18/08/2015	70	70	70	5	15	10	10	20		
25/08/2015	82	80	80	10	15	5	10	10		
01/09/2015	85	85	80	15	25	5	10	15	5-15 Unit	5-15 Unit
08/09/2015	75	75	70	5	10	5	7	5		
15/09/2015	65	60	60	5	5	5	6	5		
22/09/2015	55	55	50	5	5	4	5	4		
Average	**70.88**	**70**	**67.5**	**7.5**	**12.5**	**6.125**	**7.875**	**10.5**		

RWT – Raw Water Tank, AWT – Aerated Water Tank, CWT – Coagulated Water Tank, GSWT – Good Sedimentation Water Tank, BSWT – Bad Sedimentation Water Tank, GFWT – Good Filtration Water Tank, BFWT – Bad Filtration Water Tank, CT/TW – Contact Tank/Treated

4.16.1.2 Turbidity

The turbidity of the KNWW sampled water through its treatment tanks from the raw water tank to the contact tank are presented in Table 4.17. The presence of colloidal solids in the raw water in wet seasons mostly gives it cloudy appearances which makes it aesthetically unattractive and difficult for treatment. The turbidity of the raw water decreased through the treatment plant from an average value of 441.79 NTU to 9.80 NTU for treated water, which is significant, considering the ineffectiveness of some operation units (faulty sedimentation and filtration tanks) and the season, however, the turbidity of the treated water is above the Nigeria standard for drinking water quality, 2007. Hence, there is need to improve upon it.

Table 4.17: The turbidity (NTU) of water through the different units in KNWW treatment plant

Sampling Dates	RWT	AWT	CWT	GSWT	BSWT	GFWT	BFWT	CT/TW	WHO 1993	NIG 2007
04/08/2015	206	201	300	5.3	31	2.36	8.45	12.3		
11/08/2015	340.45	338.44	350	4.6	40.34	3.68	10.32	10.88		
18/08/2015	540	532.48	560.4	6.8	85.45	4.6	20	18.67		
25/08/2015	498.3	488	502	10	60.55	2.83	10	10.88		
01/09/2015	675	673.03	680	15	77.34	1.64	11.68	8.44	0-5 NTU	Not mentioned
08/09/2015	604	598.36	605	14.21	58.43	1.82	8.65	7.54		
15/09/2015	415	398.9	410	5	55	1.5	5	5		
22/09/2015	255.56	253	260	5.3	34	1.8	5	4.68		
Average	**441.79**	**435.40**	**458.43**	**8.28**	**55.264**	**2.53**	**9.89**	**9.80**		

RWT – Raw Water Tank, AWT – Aerated Water Tank, CWT – Coagulated Water Tank, GSWT – Good Sedimentation Water Tank, BSWT – Bad Sedimentation Water Tank, GFWT – Good Filtration Water Tank, BFWT – Bad Filtration Water Tank, CT/TW – Contact Tank/Treated Water, WHO – World Health organisation drinking water standard, NIG – Nigeria drinking water standard.

4.16.1.3 Electrical Conductivity (EC_w)

The EC_w of the KNWW sampled water through its treatment tanks from the raw water tank to the contact tank are presented in Table 4.18. The average EC_w of the raw water is 70.775 and that of the treated water is 81.5875. This suggested increase of the EC_w

due to the increased amount of alum in order to reduce the turbidity of the water, because the EC_w of a solution depends on the quantity of dissolved salts present in it. The EC_w is far above the maximum permissible level allowed by Nigeria standard for drinking water quality, 2007 and WHO drinking water standard, 1993.

Table 4.18: The EC_w (µs/m) of water through the different units in KNWW treatment plant

Sampling Dates	RWT	AWT	CWT	GSWT	BSWT	GFWT	BFWT	CT/TW	WHO 1993	NIG 2007
04/08/2015	64.7	72.04	98.4	82.5	87	83.4	84.7	83.2		
11/08/2015	69.6	71.4	121.1	82.9	98.5	83.8	84.4	82.1		
18/08/2015	80	80.8	116.9	96.2	96.3	98.8	93.3	106.4		
25/08/2015	89.7	91.5	125.2	94.5	98.3	97.8	99.2	101.6		
01/09/2015	75.4	78.2	85.3	78.8	79.8	78.4	78.9	78.4	0-2.5 µs/m	10 µs/m
08/09/2015	69.3	70.1	80.6	76.2	79.6	77.4	78.9	78.1		
15/09/2015	56.6	60.2	62.3	59.7	60.4	59.2	61.6	60.1		
22/09/2015	60.9	65.5	69.5	59.3	64.4	61.4	63.7	62.8		
Average	**70.775**	**73.7175**	**94.9125**	**78.7625**	**83.0375**	**80.025**	**80.5875**	**81.5875**		

RWT – Raw Water Tank, AWT – Aerated Water Tank, CWT – Coagulated Water Tank, GSWT – Good Sedimentation Water Tank, BSWT – Bad Sedimentation Water Tank, GFWT – Good Filtration Water Tank, BFWT – Bad Filtration Water Tank, CT/TW – Contact Tank/Treated Water, WHO – World Health organisation drinking water standard, NIG – Nigeria drinking water standard.

4.16.1.4 Total Dissolved Solids (TDS)

The TDS of the KNWW sampled water through its treatment tanks from the raw water tank to the contact tank are presented in Table 4.19. TDS describes the soluble materials in the water. The average TDS of the raw water through the treatment plant decreased, although, due to the faulty operation units, agitation of sludge along the operation units tends to cause increase in the TDS thereby affecting the quality of the treated water thus, reducing the efficiency of the treatment plant. The average TDS of the treated water is 702.5 mg/l, this value is above the threshold of Nigeria standard for drinking water quality, 2007.

Table 4.19: The TDS in mg/l of water through the different units in KNWW treatment plant

Sampling Dates	RWT	AWT	CWT	GSWT	BSWT	GFWT	BFWT	CT/TW	WHO 1993	NIG 2007
04/08/15	5050	5000	5100	840	1050	890	920	900		
11/08/15	3580	4400	3210	500	750	620	830	790		
18/08/15	8340	8550	9010	1230	1550	980	1200	1150		
25/08/15	5060	3490	4800	1050	1240	990	1140	1030		
01/09/15	7100	7040	7320	650	700	590	690	610	-	500
08/09/15	2500	2760	2470	440	580	350	420	410		
15/09/15	3420	3580	2120	470	520	210	390	310		
22/09/15	3140	2960	3220	520	650	380	440	420		
Average	**4773.75**	**4722.5**	**4656.25**	**712.5**	**880**	**626.25**	**753.75**	**702.5**		

RWT – Raw Water Tank, AWT – Aerated Water Tank, CWT – Coagulated Water Tank, GSWT – Good Sedimentation Water Tank, BSWT – Bad Sedimentation Water Tank, GFWT – Good Filtration Water Tank, BFWT – Bad Filtration Water Tank, CT/TW – Contact Tank/Treated Water, WHO – World Health organisation drinking water standard, NIG – Nigeria drinking water standard.

4.16.2 Analysis of the Physical Parameters of KNWW Water during the Wet Season using Two Ways Analysis of Variance (ANOVA)

Hypothesis:

H_o: the means of the Physical Parameters of KNWW water during wet season is not significant

H_1: the means of the Physical Parameters of KNWW water during wet season is significant.

Tests of Between-Subjects Effects

Dependent Variable: Values obtained

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Model	49420683.850[a]	11	4492789.441	4.547	.001
PHYPAR	27357566.009	3	9119188.670	9.228	.000
UNITS	9381021.950	7	1340145.993	1.356	.274
Error	20751776.595	21	988179.838		
Total	70172460.445	32			

a. R Squared = .704 (Adjusted R Squared = .549)

Conclusion One

A two-way ANOVA was conducted that examined the effect of physical parameters and units of water in KNWW treatment plant. There was a statistically significant difference between the physical parameters

$F(3,21) = 9.228$, $p = 0.0005$

Since significant value of the physical parameters (p) = 0.000 < α = 0.05, we reject H_0 and conclude that there are significant differences in the means Physical Parameters of KNWW water during wet season. Hence, this necessitate for further study.

Conclusion two

Simple main effects analysis showed that there were no differences between the units of water in KNWW Treatment Plant

Since significant value of the units in KNWW (p) = 0.274 > α = 0.05, we accept H_0 and conclude that there were no significant differences in the means Units of KNWW water during wet season.

Multiple Comparisons

Dependent Variable: Values obtained

Tukey HSD

(I) PHYSICAL PARAMETERS	(J) PHYSICAL PARAMETERS	Mean Difference (I-J)	Std. Error	Sig.	95 % Confidence Interval	
					Lower Bound	Upper Bound
COLOUR	TURBIDIDTY	-146.06300	497.036175	.991	-1531.46615	1239.34015
	ELECTRICITY CONDUCTIVITY	-48.81575	497.036175	1.000	-1434.21890	1336.58740
	TOTAL DISSOLVED SOLID	-2196.82500*	497.036175	.001	-3582.22815	-811.42185
TURBIDIDTY	COLOUR	146.06300	497.036175	.991	-1239.34015	1531.46615
	ELECTRICITY CONDUCTIVITY	97.24725	497.036175	.997	-1288.15590	1482.65040
	TOTAL DISSOLVED SOLID	-2050.76200*	497.036175	.003	-3436.16515	-665.35885
ELECTRICITY CONDUCTIVITY	COLOUR	48.81575	497.036175	1.000	-1336.58740	1434.21890
	TURBIDIDTY	-97.24725	497.036175	.997	-1482.65040	1288.15590
	TOTAL DISSOLVED SOLID	-2148.00925*	497.036175	.002	-3533.41240	-762.60610
TOTAL DISSOLVED SOLID	COLOUR	2196.82500*	497.036175	.001	811.42185	3582.22815
	TURBIDIDTY	2050.76200*	497.036175	.003	665.35885	3436.16515
	ELECTRICITY CONDUCTIVITY	2148.00925*	497.036175	.002	762.60610	3533.41240

Based on observed means.

The error term is Mean Square(Error) = 988179.838.

*. The mean difference is significant at the 0.05 level.

4.16.3 Chemical Parameters of KNWW (Water during the Wet Season)

4.16.3.1 pH

The results of the pH of the KNWW from the raw water tank through the contact tank as determined from the department of water resources and environmental engineering laboratory are shown in Table 4.20. The average pH values through the treatment plant have its minimum pH value as 6.2 in CWT and maximum pH value as 6.7875 in RWT. This indicated the impact of the coagulant, Alum, to the water as a result of the hydrolysis of the alum and formation of more hydrogen ions than hydroxide ions. The

pH of the treated water in the contact tank is within Nigeria for drinking water quality, 2007 and WHO drinking water standard, 1993.

Table 4.20: The pH of water through the different units in the KNWW treatment plant

Sampling Dates	RWT	AWT	CWT	GSWT	BSWT	GFWT	BFWT	CT/TW	WHO 1993	NIG 2007
04/08/2015	6.6	6.5	6.1	6.4	6.5	6.4	6.3	6.3		
11/08/2015	6.8	6.6	6.2	6.3	6.4	6.3	6.3	6.5		
18/08/2015	6.1	6.1	5.5	5.8	5.6	5.9	6	6.1		
25/08/2015	6.9	7	6.7	6.6	6.7	6.6	6.5	6.7		
01/09/2015	7.4	7.2	6.2	7	6.9	7.1	7	7.1		6.5 - 8.5
08/09/2015	6.7	6.8	6.1	6.3	6.4	6.4	6.3	6.4		
15/09/2015	6.8	6.7	6.2	6.3	6.2	6.4	6.5	6.5		
22/09/2015	7	6.8	6.6	6.7	6.6	6.7	6.8	6.9		
Average	**6.7875**	**6.7125**	**6.2**	**6.425**	**6.4125**	**6.475**	**6.4625**	**6.5625**		

RWT – Raw Water Tank, AWT – Aerated Water Tank, CWT – Coagulated Water Tank, GSWT – Good Sedimentation Water Tank, BSWT – Bad Sedimentation Water Tank, GFWT – Good Filtration Water Tank, BFWT – Bad Filtration Water Tank, CT/TW – Contact Tank/Treated Water, WHO – World Health organisation drinking water standard, NIG – Nigeria drinking water standard.

4.16.3.2 Nitrate

The concentration of nitrate from the raw water through the treatment plant is shown in Table 4.21. The average concentration of nitrate in the treated water ready for distribution is 6.6625 mg/l, which is far below the permissible recommended limits of nitrate in water according to Nigeria standard for drinking water quality, 2007 and WHO drinking water standard, 1993. As such, the treated water is safe for consumption in terms of nitrate concentration especially because of infants who are at higher risk to blue babies syndrome.

Table 4.21: The Nitrate in mg/l of water through the different units in KNWW treatment plant

Sampling Dates	RWT	AWT	CWT	GSWT	BSWT	GFWT	BFWT	CT/TW	WHO 1993	NIG 2007
04/08/2015	35	14	7	0	0	7	7	14		
11/08/2015	50.3	16	4.4	2.5	6.8	3.6	3.6	6.8		
18/08/2015	68.3	20.6	9.3	1.4	2.1	8.3	9.5	16.4		
25/08/2015	46.2	12	10.4	3.4	7.8	2.4	3.7	4.3		
01/09/2015	20.5	5	5	0	0	2.5	2.5	5		
08/09/2015	15	3.4	1.8	1.2	1.5	1	1.2	1	50	50
15/09/2015	5.6	3.5	4	2.6	4.9	2.8	2.6	3.5		
22/09/2015	10.8	2.9	1.8	1	1.2	0.6	1	2.3		
Average	**31.4625**	**9.675**	**5.4625**	**1.5125**	**3.0375**	**3.525**	**3.8875**	**6.6625**		

RWT – Raw Water Tank, AWT – Aerated Water Tank, CWT – Coagulated Water Tank, GSWT – Good Sedimentation Water Tank, BSWT – Bad Sedimentation Water Tank, GFWT – Good Filtration Water Tank, BFWT – Bad Filtration Water Tank, CT/TW – Contact Tank/Treated Water, WHO – World Health organisation drinking water standard, NIG – Nigeria drinking water standard.

4.16.3.3 Chloride

Chloride concentrations along the treatment processes and unit operations are shown in Table 4.22. The average chloride concentration of the treated water ready for distribution is 7.00125 mg/l which is far below the permissible recommended limits for Nigeria standard of drinking water quality, 2007 and WHO drinking water standard, 1993. They are responsible for brackish taste in water and are an indicator of sewage pollution because of the chloride content of urine (Tebutt, 1998). They also affect the solubility of oxygen in water thereby reducing the saturation of dissolved oxygen concentration.

Table 4.22: The Chloride in mg/l of water through the different units in KNWW treatment plant

Sampling Dates	RWT	AWT	CWT	GSWT	BSWT	GFWT	BFWT	CT/TW	WHO 1993	NIG 2007
04/08/2015	5.49	6.49	11.99	5.99	5.49	6.49	6.49	8.99		
11/08/2015	9.34	10.23	13.09	7.22	6.98	7.44	7.02	8.56		
18/08/2015	8.9	5.34	8.44	3.46	3.55	2.56	3.42	4.68		
25/08/2015	12.04	11.99	10.4	6.48	7.8	4.3	7.8	6.84		
01/09/2015	10.66	12.49	16.55	11.62	13.09	9.01	10.66	11.24	250	250
08/09/2015	7.47	8.56	8.98	3.49	4.73	3.08	3.8	3.22		
15/09/2015	6.49	4.99	5.48	5.99	6.49	7.49	6.99	5.49		
22/09/2015	3.49	9.99	7.54	6.99	10.49	5.49	8.49	6.99		
Average	**7.985**	**8.76**	**10.30875**	**6.405**	**7.3275**	**5.7325**	**6.83375**	**7.00125**		

RWT – Raw Water Tank, AWT – Aerated Water Tank, CWT – Coagulated Water Tank, GSWT – Good Sedimentation Water Tank, BSWT – Bad Sedimentation Water Tank, GFWT – Good Filtration Water Tank, BFWT – Bad Filtration Water Tank, CT/TW – Contact Tank/Treated Water, WHO – World Health organisation drinking water standard, NIG – Nigeria drinking water standard.

4.16.3.4 Alkalinity

The alkalinity of the raw water through the treatment plant is presented in Table 4.23. The average concentration of alkalinic ions in the treated water ready for distribution is 13.6875 as against its raw water concentration of 25.5. The decrease in the alkalinity of the raw water was as a result of the application of the coagulant which is shown drastic decrease as a result of the chemical hydrolysis of the coagulant thereby neutralizing the presences of some alkaline components.

Table 4.23: The Alkalinity in mg/l of water through the different units in KNWW treatment plant

Sampling Dates	RWT	AWT	CWT	GSWT	BSWT	GFWT	BFWT	CT/TW	WHO 1993	NIG 2007
04/08/2015	22	21	8	10	15	15	12	13		
11/08/2015	25	18	10	12	14	15	14	12.5		
18/08/2015	32	26	9.5	12	7.5	17	10	15		
25/08/2015	24	24	7	14	14	16	14	16		
01/09/2015	22	18	6	9	11	12	10	11		
08/09/2015	21	19.5	5.5	8	12	11	9	10	-	-
15/09/2015	28	21	8	11	14	16	14	14		
22/09/2015	30	25	12	16	18	19	13	18		
Average	**25.5**	**21.5625**	**8.25**	**11.5**	**13.1875**	**15.125**	**12**	**13.6875**		

RWT – Raw Water Tank, AWT – Aerated Water Tank, CWT – Coagulated Water Tank, GSWT – Good Sedimentation Water Tank, BSWT – Bad Sedimentation Water Tank, GFWT – Good Filtration Water Tank, BFWT – Bad Filtration Water Tank, CT/TW – Contact Tank/Treated Water, WHO – World Health organisation drinking water standard, NIG – Nigeria drinking water standard.

4.16.3.5 Acidity

The alkalinity of the raw water through the treatment plant is presented in Table 4.24. The average concentration of acidic ions in the treated water ready for distribution is 17.5625 as against its raw water concentration of 10.5. The increase in the acidity of the water was as a result of the application of the coagulant in CWT which impacted drastically by increasing the production of the hydrogen ions via the chemical hydrolysis of the coagulant more than the alkaline component hydroxide ions, thereby speedily neutralizing the presences of some of the alkaline components.

Table 4.24: The Acidity in mg/l of water through the different units in KNWW treatment plant

Sampling Dates	RWT	AWT	CWT	GSWT	BSWT	GFWT	BFWT	CT/TW	WHO 1993	NIG 2007
04/08/2015	11	13.5	40	34	22	20	14.5	19.5		
11/08/2015	11	14.5	38.5	8.5	10	10	12.5	11.5		
18/08/2015	6.5	10	42.5	18.5	16	19	20	19.5		
25/08/2015	8	5.5	51.5	14	17	16	18	16.5		
01/09/2015	12	11.5	34.6	9	11	14	17	15		
08/09/2015	10.5	14	39.5	16	18	15	20	21	-	-
15/09/2015	13.5	12.4	40.8	15	13	19	21	19.5		
22/09/2015	11.5	12	36.5	15.5	16	19	13	18		
Average	**10.5**	**11.675**	**40.4875**	**16.3125**	**15.375**	**16.5**	**17**	**17.5625**		

RWT – Raw Water Tank, AWT – Aerated Water Tank, CWT – Coagulated Water Tank, GSWT – Good Sedimentation Water Tank, BSWT – Bad Sedimentation Water Tank, GFWT – Good Filtration Water Tank, BFWT – Bad Filtration Water Tank, CT/TW – Contact Tank/Treated Water, WHO – World Health organisation drinking water standard, NIG – Nigeria drinking water standard.

4.16.3.6 Hardness

The hardness of the raw water through the treatment plant is presented in Table 4.25. This is the property of water which prevents lather formation with soap and produces scale in hot water system. The result shows that the raw water hardness had an average of 152.6875mg/l, but at the sedimentation operations, it decreased to 97.6mg/l in the effective sedimentation tank as a result of precipitation of the metallic ions responsible for the hardness of the water due to flocculation.

Table 4.25: The hardness in mg/l of water through the different units in KNWW treatment plant

Sampling Dates	RWT	AWT	CWT	GSWT	BSWT	GFWT	BFWT	CT/TW	WHO 1993	NIG 2007
04/08/2015	141.4	121.2	121.2	80.8	111.1	212.1	131.3	171.7		
11/08/2015	134.4	127.9	122.6	74.3	104.7	98.5	108.4	121.4		
18/08/2015	131.2	119.8	124.5	92.4	161.7	101.9	109.2	126.4		
25/08/2015	161.3	151.4	148.9	118.3	125.3	121.8	139.4	151.2		
01/09/2015	158.2	135.2	135.2	100	106.4	125.4	151.5	131.8		
08/09/2015	162.8	144.2	144.2	106.2	115.2	115.2	125.8	121.8	150	150
15/09/2015	151	148.4	149.1	99.2	113	110.8	141.6	125.2		
22/09/2015	181.2	154.6	154.9	109.6	125.8	121.6	136.4	128.4		
Average	**152.6875**	**137.8375**	**137.575**	**97.6**	**120.4**	**125.9125**	**130.45**	**134.7375**		

RWT – Raw Water Tank, AWT – Aerated Water Tank, CWT – Coagulated Water Tank, GSWT – Good Sedimentation Water Tank, BSWT – Bad Sedimentation Water Tank, GFWT – Good Filtration Water Tank, BFWT – Bad Filtration Water Tank, CT/TW – Contact Tank/Treated Water, WHO – World Health organisation drinking water standard, NIG – Nigeria drinking water standard.

4.16.3.7 Residual Chlorine

The chlorine concentration of the water through the treatment plant is presented in Table 4.26. The concentration of chlorine from the result shown suggests that post-chlorination of the water was not carried out in any case. The average residual chlorine in the treated water was 0.02875 mg/l, which is a little far from the minimum recommended permissible limit for Nigeria standard of drinking water quality, 2007 and WHO drinking water standard, 1993. This can be attributed to the faulty chlorination pump. Hence, recontamination of contaminant can be possible along service pipes.

Table 4.26: The Residual Chlorine in mg/l of water through the different units in KNWW treatment plant

Sampling Dates	RWT	AWT	CWT	GSWT	BSWT	GFWT	BFWT	CT/TW	WHO 1993	NIG 2007
04/08/2015	0.04	0.04	0.05	0.02	0.02	0.02	0.02	0.02		
11/08/2015	0.04	0.04	0.03	0.02	0.01	0.01	0.01	0.01		
18/08/2015	0.06	0.05	0.06	0.05	0.05	0.06	0.05	0.06		
25/08/2015	0.03	0.03	0.04	0.05	0.03	0.05	0.03	0.05		
01/09/2015	0.05	0.02	0.02	0.03	0.02	0.03	0.05	0.03	0.2-2.5	0.2-5
08/09/2015	0.03	0.04	0.04	0.02	0.02	0.02	0.02	0.02		
15/09/2015	0.06	0.04	0.05	0.03	0.02	0.02	0.03	0.02		
22/09/2015	0.02	0.02	0.02	0.01	0.01	0.02	0.01	0.02		
Average	**0.04125**	**0.035**	**0.03875**	**0.02875**	**0.0225**	**0.02875**	**0.0275**	**0.02875**		

RWT – Raw Water Tank, AWT – Aerated Water Tank, CWT – Coagulated Water Tank, GSWT – Good Sedimentation Water Tank, BSWT – Bad Sedimentation Water Tank, GFWT – Good Filtration Water Tank, BFWT – Bad Filtration Water Tank, CT/TW – Contact Tank/Treated Water, WHO – World Health organisation drinking water standard, NIG – Nigeria drinking water standard.

4.16.3.8 Dissolved Oxygen (DO)

The concentration of dissolved oxygen in the water through the treatment plant is presented in Table 4.27. The concentration of dissolved oxygen in the water as it passed through the processes and unit operations were relatively the same in amount. However, a small decrease in amount was observed in the unit operations (sedimentation and filtration). This could be attributed to the reduced vibration and agitation of water in these tanks. Oxygen is a very important element in water quality control as its presence in drinking water is desired because oxygen-saturated waters have a pleasant taste and waters lacking DO have an insipid taste (Tebbutt, 1998)

Table 4.27: The DO in mg/l of water through the different units in KNWW treatment plant

Sampling Dates	RWT	AWT	CWT	GSWT	BSWT	GFWT	BFWT	CT/TW	WHO 1997	NIG 2007
04/08/2015	2.7	2.1	2.7	2.5	2.6	2.6	2.4	2.6		
11/08/2015	3.5	3.6	3.3	3.6	3.4	3.5	3.3	3.4		
18/08/2015	3.2	2.9	3.2	3.1	3	3	2.8	2.9		
25/08/2015	2.4	3	3.2	2.9	2.4	2.6	2.6	2.7		
01/09/2015	3.3	3.4	3.4	2.8	3	3.1	3.2	3.1		
08/09/2015	2.9	2.2	2.8	2	2.6	2.4	2.4	2.4		
15/09/2015	3.8	3.4	3.5	3.3	3.5	3.2	3.1	3.3		
22/09/2015	3	2.6	2.9	2.4	2.5	2.6	2.6	2.6		
Average	**3.1**	**2.9**	**3.125**	**2.825**	**2.875**	**2.875**	**2.8**	**2.875**		

RWT – Raw Water Tank, AWT – Aerated Water Tank, CWT – Coagulated Water Tank, GSWT – Good Sedimentation Water Tank, BSWT – Bad Sedimentation Water Tank, GFWT – Good Filtration Water Tank, BFWT – Bad Filtration Water Tank, CT/TW – Contact Tank/Treated Water, WHO – World Health organisation drinking water standard, NIG – Nigeria drinking water standard.

4.16.4 Bacteriological Count

The results of the bacteriological count of the water through the treatment plant are shown in Table 4.28. This result further shows that the residual chlorine from the treatment plant is not sufficient to destroy the bacteria in the water. The average bacteria count of the treated water is 2.25 ml per 100. This may suggest that, post chlorination of treated water is not usually carried out. The average bacteria count of the treated water in the contact tank is above the recommended permissible limit for Nigeria standard of drinking water quality, 2007 and WHO drinking water standard, 1993.

Table 4.28: Bacteriological count in mg/l of water through the different units in KNWW treatment plant

Sampling Dates	RWT 10^3	AWT 10^3	CWT 10^3	GSWT 10^3	BSWT 10^3	GFWT 10^3	BFWT 10^3	CT/TW 10^2	WHO (1993) 10^2	NIG (2007) 10^2
04/08/2015	160	160	7	2	6	6	9	2		
11/08/2015	140	140	9	6	2	5	5	4		
18/08/2015	100	90	20	2	2	2	2	2		
25/08/2015	160	150	8	3	2	2	2	2		
01/09/2015	15	160	13	5	30	3	15	6	0	1
08/09/2015	160	160	11	4	6	1	2	1		
15/09/2015	120	110	5	2	2	1	1	1		
22/09/2015	60	70	4	3	3	0	1	0		
Average	**114.375**	**130**	**9.625**	**3.375**	**6.625**	**2.5**	**4.625**	**2.25**		

RWT – Raw Water Tank, AWT – Aerated Water Tank, CWT – Coagulated Water Tank, GSWT – Good Sedimentation Water Tank, BSWT – Bad Sedimentation Water Tank, GFWT – Good Filtration Water Tank, BFWT – Bad Filtration Water Tank, CT/TW – Contact Tank/Treated Water, WHO – World Health organisation drinking water standard, NIG – Nigeria drinking water standard.

4.16.5 Analysis of the chemical Parameters of KNWW Water during the Wet Season using Two Ways Analysis of Variance (ANOVA)

Hypothesis:

H_o: the means of the chemical Parameters of KNWW water during wet season is not significant

H_1: the means of the chemical Parameters of KNWW water during wet season is significant

Tests of Between-Subjects Effects

Dependent Variable: Values obtained

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Model	154247.399[a]	16	9640.462	27.497	.000
CHEPAR	105805.531	8	13225.691	37.723	.000
UNITS	4523.649	7	646.236	1.843	.097
Error	19633.658	56	350.601		
Total	173881.057	72			

a. R Squared = .887 (Adjusted R Squared = .855)

Conclusion One

A two-way ANOVA was conducted that examined the effect of chemical parameters and units of water in KNWW treatment plant. There was a statistically significant difference between the chemical parameters

F (8,56) = 37.723, *p = 0.0005*

Since significant value of the chemical parameters (p) = 0.000 < α = 0.05, we reject H_0 and conclude that there are significant differences in the means chemical Parameters of KNWW water during wet season. Hence, this necessitate for further study.

Conclusion two

Simple main effects analysis showed that there were no differences between the units of water in KNWW Treatment Plant

Since significant value of the units in KNWW (p) = 0.097 > α = 0.05, we accept H_0 and conclude that there were no significant differences in the means Units of KNWW water during wet season.

Multiple Comparisons

Dependent Variable: Values obtained

Tukey HSD

(I) PHYSICAL PARAMETERS	(J) PHYSICAL PARAMETERS	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
pH	NITRATE	-1.64856	9.362172	1.000	-31.85146	28.55434
	CHLORIDE	-1.03938	9.362172	1.000	-31.24228	29.16353
	ALKALINITY	-8.59675	9.362172	.991	-38.79965	21.60615
	ACIDITY	-11.67162	9.362172	.942	-41.87453	18.53128
	HARDNESS	-123.16794*	9.362172	.000	-153.37084	-92.96504
	RESIDUAL CHLORINE	6.47347	9.362172	.999	-23.72943	36.67637
	DISSOLVED OXYGEN	3.58306	9.362172	1.000	-26.61984	33.78596

	BACTERIOLOGY COUNT	-27.66694	9.362172	.097	-57.86984	2.53596
	pH	1.64856	9.362172	1.000	-28.55434	31.85146
	CHLORIDE	.60919	9.362172	1.000	-29.59371	30.81209
	ALKALINITY	-6.94819	9.362172	.998	-37.15109	23.25471
	ACIDITY	-10.02306	9.362172	.976	-40.22596	20.17984
	HARDNESS	-121.51937*	9.362172	.000	-151.72228	-91.31647
NITRATE	RESIDUAL CHLORINE	8.12203	9.362172	.994	-22.08087	38.32493
	DISSOLVED OXYGEN	5.23163	9.362172	1.000	-24.97128	35.43453
	BACTERIOLOGY COUNT	-26.01838	9.362172	.145	-56.22128	4.18453
	pH	1.03938	9.362172	1.000	-29.16353	31.24228
	NITRATE	-.60919	9.362172	1.000	-30.81209	29.59371
	ALKALINITY	-7.55737	9.362172	.996	-37.76028	22.64553
	ACIDITY	-10.63225	9.362172	.966	-40.83515	19.57065
	HARDNESS	-122.12856*	9.362172	.000	-152.33146	-91.92566
CHLORIDE	RESIDUAL CHLORINE	7.51284	9.362172	.996	-22.69006	37.71575
	DISSOLVED OXYGEN	4.62244	9.362172	1.000	-25.58046	34.82534
	BACTERIOLOGY COUNT	-26.62756	9.362172	.126	-56.83046	3.57534
	pH	8.59675	9.362172	.991	-21.60615	38.79965
	NITRATE	6.94819	9.362172	.998	-23.25471	37.15109
	CHLORIDE	7.55737	9.362172	.996	-22.64553	37.76028
	ACIDITY	-3.07487	9.362172	1.000	-33.27778	27.12803
	HARDNESS	-114.57119*	9.362172	.000	-144.77409	-84.36829
ALKALINITY	RESIDUAL CHLORINE	15.07022	9.362172	.795	-15.13268	45.27312
	DISSOLVED OXYGEN	12.17981	9.362172	.927	-18.02309	42.38271
	BACTERIOLOGY COUNT	-19.07019	9.362172	.525	-49.27309	11.13271
	pH	11.67162	9.362172	.942	-18.53128	41.87453
	NITRATE	10.02306	9.362172	.976	-20.17984	40.22596
	CHLORIDE	10.63225	9.362172	.966	-19.57065	40.83515
ACIDITY	ALKALINITY	3.07487	9.362172	1.000	-27.12803	33.27778
	HARDNESS	-111.49631*	9.362172	.000	-141.69921	-81.29341
	RESIDUAL CHLORINE	18.14509	9.362172	.591	-12.05781	48.34800

	DISSOLVED OXYGEN	15.25469	9.362172	.785	-14.94821	45.45759
	BACTERIOLOGY COUNT	-15.99531	9.362172	.739	-46.19821	14.20759
	pH	123.16794*	9.362172	.000	92.96504	153.37084
	NITRATE	121.51937*	9.362172	.000	91.31647	151.72228
	CHLORIDE	122.12856*	9.362172	.000	91.92566	152.33146
	ALKALINITY	114.57119*	9.362172	.000	84.36829	144.77409
	ACIDITY	111.49631*	9.362172	.000	81.29341	141.69921
HARDNESS	RESIDUAL CHLORINE	129.64141*	9.362172	.000	99.43850	159.84431
	DISSOLVED OXYGEN	126.75100*	9.362172	.000	96.54810	156.95390
	BACTERIOLOGY COUNT	95.50100*	9.362172	.000	65.29810	125.70390
	pH	-6.47347	9.362172	.999	-36.67637	23.72943
	NITRATE	-8.12203	9.362172	.994	-38.32493	22.08087
	CHLORIDE	-7.51284	9.362172	.996	-37.71575	22.69006
	ALKALINITY	-15.07022	9.362172	.795	-45.27312	15.13268
RESIDUAL	ACIDITY	-18.14509	9.362172	.591	-48.34800	12.05781
CHLORINE	HARDNESS	-129.64141*	9.362172	.000	-159.84431	-99.43850
	DISSOLVED OXYGEN	-2.89041	9.362172	1.000	-33.09331	27.31250
	BACTERIOLOGY COUNT	-34.14041*	9.362172	.016	-64.34331	-3.93750
	pH	-3.58306	9.362172	1.000	-33.78596	26.61984
	NITRATE	-5.23163	9.362172	1.000	-35.43453	24.97128
	CHLORIDE	-4.62244	9.362172	1.000	-34.82534	25.58046
	ALKALINITY	-12.17981	9.362172	.927	-42.38271	18.02309
DISSOLVED	ACIDITY	-15.25469	9.362172	.785	-45.45759	14.94821
OXYGEN	HARDNESS	-126.75100*	9.362172	.000	-156.95390	-96.54810
	RESIDUAL CHLORINE	2.89041	9.362172	1.000	-27.31250	33.09331
	BACTERIOLOGY COUNT	-31.25000*	9.362172	.037	-61.45290	-1.04710
	pH	27.66694	9.362172	.097	-2.53596	57.86984
	NITRATE	26.01838	9.362172	.145	-4.18453	56.22128
BACTERIOLOGY	CHLORIDE	26.62756	9.362172	.126	-3.57534	56.83046
COUNT	ALKALINITY	19.07019	9.362172	.525	-11.13271	49.27309
	ACIDITY	15.99531	9.362172	.739	-14.20759	46.19821
	HARDNESS	-95.50100*	9.362172	.000	-125.70390	-65.29810

	RESIDUAL CHLORINE	34.14041*	9.362172	.016	3.93750	64.34331
	DISSOLVED OXYGEN	31.25000*	9.362172	.037	1.04710	61.45290

Based on observed means.
The error term is Mean Square (Error) = 350.601.
*. The mean difference is significant at the .05 level.

4.17 Water Quality Parameters- Seasonal Analysis

4.17.1 Physical Parameters of KNWW Water during the Dry Season

4.17.1.1 Colour

The colour of the KNWW sampled water through its treatment tanks from the raw water tank to the contact tank are presented in Table 4.29. The average values through the treatment processes and operations showed decrease in the colouration of the water however, BSWT and BFWT were not operating effectively as due to broken laid bed in that operation units. These faulty beds agitate the settled suspended solids leading to increased water colour which affects the efficiency of the treatment plant. The average colour of the treated water is 4.25unit which shows significant decrease when compared to the intake, raw water colour with average 27.5 unit. The average colour of the treated water is within the threshold value of Nigeria standard for drinking water quality, 2007 and WHO drinking water standard, 1993.

Table 4.29: The colour (Unit) of water through the different units in KNWW treatment plant

Sampling Dates	RWT	AWT	CWT	GSWT	BSWT	GFWT	BFWT	CT/TW	WHO 1993	NIG 2007
06/10/2015	50	50	50	5	10	5	5	5		
13/10/2015	40	40	30	5	15	4	10	5		
20/10/2015	35	30	30	5	10	4	5	4		
27/10/2015	30	30	30	4	5	4	5	4		
03/11/2015	20	20	10	5	20	5	10	5	5-15 Unit	5-15 Unit
10/11/2015	20	20	10	4	5	4	5	4		
17/11/2015	15	15	15	5	5	4	5	3		
24/11/2015	10	10	10	5	5	4	5	4		
Average	**27.5**	**26.875**	**23.125**	**4.75**	**9.375**	**4.25**	**6.25**	**4.25**		

RWT – Raw Water Tank, AWT – Aerated Water Tank, CWT – Coagulated Water Tank, GSWT – Good Sedimentation Water Tank, BSWT – Bad Sedimentation Water Tank, GFWT – Good Filtration Water Tank, BFWT – Bad Filtration Water Tank, CT/TW – Contact Tank/Treated Water, WHO – World Health organisation drinking water standard, NIG – Nigeria drinking water standard.

4.17.1.2 Turbidity

The turbidity of the KNWW sampled water through its treatment tanks from the raw water tank to the contact tank are presented in Table 4.30. The presence of colloidal solids in the raw water in dry season is far less to its presence during the wet seasons mostly especially due to the runoff over land surfaces which gives surface water it a cloudy appearances and which makes it aesthetically unattractive and difficult for treatment. The turbidity of the raw water decreased through the treatment plant from an average value of 131.635 NTU to 4.95125 NTU for treated water, which is significantly good as it is below the threshold limits for Nigeria standard for drinking water quality, 2007. Comparing this result to wet season, more work is usually done in the KNWW during the wet season because raw waters highly turbid in wet season.

Table 4.30: The turbidity (NTU) of water through the different units in KNWW treatment plant

Sampling Dates	RWT	AWT	CWT	GSWT	BSWT	GFWT	BFWT	CT/TW	WHO 1993	NIG 2007
06/10/15	213.92	211.52	220	5.1	25	1.57	5	4.44		
13/10/15	206	201	300	5.3	31	2.36	8.45	6.14		
20/10/15	186.99	185.24	190	4.8	14.04	4.6	9.12	5		
27/10/15	148	139	145.45	7.29	15.56	3.23	11.72	6.9		
03/11/15	97	100	103.43	5.6	10.34	1.64	9.06	5	0-5 NTU	Not Mention
10/11/15	80.48	72.8	77.05	4.29	8.35	1.82	8.65	4.53		
17/11/15	66.2	71.8	79.98	5	3.89	1.5	5	3.6		
24/11/15	54.49	52	56.44	5.3	34	1.8	5	4		
Average	**131.635**	**129.17**	**146.5438**	**5.335**	**17.7725**	**2.315**	**7.75**	**4.95125**		

RWT – Raw Water Tank, AWT – Aerated Water Tank, CWT – Coagulated Water Tank, GSWT – Good Sedimentation Water Tank, BSWT – Bad Sedimentation Water Tank, GFWT – Good Filtration Water Tank, BFWT – Bad Filtration Water Tank, CT/TW – Contact Tank/Treated Water, WHO – World Health organisation drinking water standard, NIG – Nigeria drinking water standard.

4.17.1.3 Electrical Conductivity (EC_w)

The EC_w of the KNWW sampled water through its treatment tanks from the raw water tank to the contact tank are presented in Table 4.31. The average EC_w of the raw water is 64.3125 and that of the treated water is 70.4625. This suggests that large quantity of chemicals (e.g coagulants) is used in the treatment processes that boosted the quantity of salts present in the solution. The EC_w of a solution depends on the quantity of dissolved salts present in it. The EC_w is far above the maximum permissible level allowed by Nigeria standard for drinking water quality, 2007 and WHO drinking water standard, 1993.

Table 4.31: The EC_w (µs/m) of water through the different units in treatment plant

Sampling Dates	RWT	AWT	CWT	GSWT	BSWT	GFWT	BFWT	CT/TW	WHO 1997	NIG 2007
06/10/15	65.4	71.4	84.4	82.5	87.2	82.3	83.6	81.3		
13/10/15	70.5	73.5	90.2	82.9	95.3	81.4	85.2	79.8		
20/10/15	68.4	71.4	85.7	74.2	79.3	76.2	79.8	78.5		
27/10/15	60.9	65.5	69.5	59.3	64.4	61.4	63.7	62.8		
03/11/15	62.4	65.4	67.2	63.5	65.8	63.9	64.6	64.3	0-2.5 µs/m	10 µs/m
10/11/15	59.5	61.2	65.3	63.4	64.3	63.9	65.5	63.6		
17/11/15	61.5	62.8	63.4	61.2	62.5	61.6	62.8	61.9		
24/11/15	65.9	67.4	73.4	69.5	71.8	70.3	72.3	71.5		
Average	**64.3125**	**67.325**	**74.8875**	**69.5625**	**73.825**	**70.125**	**72.1875**	**70.4625**		

RWT – Raw Water Tank, AWT – Aerated Water Tank, CWT – Coagulated Water Tank, GSWT – Good Sedimentation Water Tank, BSWT – Bad Sedimentation Water Tank, GFWT – Good Filtration Water Tank, BFWT – Bad Filtration Water Tank, CT/TW – Contact Tank/Treated Water, WHO – World Health organisation drinking water standard, NIG – Nigeria drinking water standard.

4.17.1.4 Total Dissolved Solids (TDS)

The TDS of the KNWW sampled water through its treatment tanks from the raw water tank to the contact tank are presented in Table 4.32. TDS describes the soluble materials in the water. The average TDS of the raw water through the treatment plant decreased, although, due to the faulty pulsators in the operation units, agitation of sludge along the operation units tends to cause increase in the TDS thereby affecting the quality of the treated water thus, reducing the efficiency of the treatment plant. The average TDS of the treated water is 198.75 mg/l, this value is within the threshold of Nigeria standard for drinking water quality, 2007.

Table 4.32: The TDS in mg/l of water through the different units in KNWW treatment plant

Sampling Dates	RWT	AWT	CWT	GSWT	BSWT	GFWT	BFWT	CT/TW	WHO 1993	NIG 2007
06/10/2015	2430	1960	2210	570	610	420	490	380	-	500
13/10/2015	2670	2510	3210	500	620	480	570	500		
20/10/2015	940	890	1010	220	360	160	240	190		
27/10/2015	420	410	320	120	190	100	140	110		
03/11/2015	630	320	450	130	180	90	120	100		
10/11/2015	250	190	240	110	140	80	100	90		
17/11/2015	140	160	180	200	160	100	140	120		
24/11/2015	170	150	10	160	140	30	120	100		
Average	**956.25**	**823.75**	**953.75**	**251.25**	**300**	**182.5**	**240**	**198.75**		

RWT – Raw Water Tank, AWT – Aerated Water Tank, CWT – Coagulated Water Tank, GSWT – Good Sedimentation Water Tank, BSWT – Bad Sedimentation Water Tank, GFWT – Good Filtration Water Tank, BFWT – Bad Filtration Water Tank, CT/TW – Contact Tank/Treated Water, WHO – World Health organisation drinking water standard, NIG – Nigeria drinking water standard.

4.17.2 Analysis of the Physical Parameters of KNWW Water during the dry Season using Two Ways Analysis of Variance (ANOVA)

Tests of Between-Subjects Effects

Dependent Variable: Values obtained

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Model	2296749.269[a]	11	208795.388	7.467	.000
UNITS	323603.305	7	46229.044	1.653	.175
PHYPAR	1185387.136	3	395129.045	14.131	.000
Error	587182.701	21	27961.081		
Total	2883931.970	32			

a. R Squared = .796 (Adjusted R Squared = .690)

Conclusion One

A two-way ANOVA was conducted that examined the effect of physical parameters and units of water in KNWW treatment plant. There was a statistically significant difference between the physical parameters

F (3,21) = 14.131, *p = 0.0005*

Since significant value of the chemical parameters (*p*) = 0.000 < α = 0.05, we reject H_0 and conclude that there are significant differences in the means physical Parameters of KNWW water during wet season. Hence, this necessitate for further study.

Conclusion Two

Simple main effects analysis showed that there were also differences between the units of water in KNWW Treatment Plant

Since significant value of the units in KNWW (p) = 0.175 > α = 0.05, we also reject H_0 and conclude that there were statistically significant differences in the means Units of KNWW water during dry season.

Multiple Comparisons

Dependent Variable: VALUES OBTAINED

Tukey HSD

(I) PHYSICAL PARAMETERS	(J) PHYSICAL PARAMETERS	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
COLOUR	TURBIDTY	-42.38719	83.607836	.957	-275.42971	190.65532
	ELECTRICITY CONDUCTIVITY	-57.03906	83.607836	.903	-290.08158	176.00345
	TOTAL DISSOLVED SOLID	-474.98438*	83.607836	.000	-708.02689	-241.94186
TURBIDIDTY	COLOUR	42.38719	83.607836	.957	-190.65532	275.42971
	ELECTRICITY CONDUCTIVITY	-14.65187	83.607836	.998	-247.69438	218.39064
	TOTAL DISSOLVED SOLID	-432.59718*	83.607836	.000	-665.63969	-199.55467
ELECTRICITY CONDUCTIVITY	COLOUR	57.03906	83.607836	.903	-176.00345	290.08158
	TURBIDIDTY	14.65187	83.607836	.998	-218.39064	247.69438
	TOTAL DISSOLVED SOLID	-417.94531*	83.607836	.000	-650.98783	-184.90280
TOTAL DISSOLVED SOLID	COLOUR	474.98438*	83.607836	.000	241.94186	708.02689
	TURBIDIDTY	432.59718*	83.607836	.000	199.55467	665.63969
	ELECTRICITY CONDUCTIVITY	417.94531*	83.607836	.000	184.90280	650.98783

Based on observed means.

The error term is Mean Square (Error) = 27961.081.

*. The mean difference is significant at the .05 level.

4.17.3 Chemical Parameters of KNWW Water during the dry Season

4.17.3.1 pH

The results of the pH of the KNWW from the raw water tank through the contact tank are shown in Table 4.33. The average pH values through the treatment plant have its minimum pH value as 7.0625 in CWT and maximum pH value as 7.5125 in RWT. This indicated the impact of the coagulant, Alum, to the water as it hydrolysed. The

hydrolysis of alum is accompanied with the formation of more hydrogen ions than hydroxide ions. The pH of the treated water in the contact tank is within Nigeria for drinking water quality, 2007 and WHO drinking water standard, 1993.

Table 4.33: The pH of water through the different units in the KNWW treatment plant

Sampling Dates	RWT	AWT	CWT	GSWT	BSWT	GFWT	BFWT	CT/TW	WHO 1993	NIG 2007
06/10/2015	7.4	7.3	6.8	7	7	7.1	7	7.1		
13/10/2015	6.9	6.8	6.5	6.7	6.6	6.8	6.7	6.8	6.5-8.5	6.5-8.5
20/10/2015	7.5	7.4	6.9	7.2	7.1	7.3	6.9	7.1		
27/10/2015	7.9	7.8	7.4	7.6	7.5	7.8	7.7	7.8		
03/11/2015	8.1	7.9	7.7	7.8	7.7	7.9	7.7	7.9		
10/11/2015	7.4	7.4	7.1	7.2	7	7.3	7.1	7.2		
17/11/2015	7.8	7.9	7.5	7.6	7.4	7.7	7.5	7.6		
24/11/2015	7.1	6.9	6.6	6.7	6.6	6.7	6.8	6.9		
Average	**7.5125**	**7.425**	**7.0625**	**7.225**	**7.1125**	**7.325**	**7.175**	**7.3**		

RWT – Raw Water Tank, AWT – Aerated Water Tank, CWT – Coagulated Water Tank, GSWT – Good Sedimentation Water Tank, BSWT – Bad Sedimentation Water Tank, GFWT – Good Filtration Water Tank, BFWT – Bad Filtration Water Tank, CT/TW – Contact Tank/Treated Water, WHO – World Health organisation drinking water standard, NIG – Nigeria drinking water standard.

4.17.3.2 Nitrate

The concentration of nitrate from the raw water through the treatment plant is shown in Table 4.34. The average concentration of nitrate in the raw water at the intake was 5.75 mg/l, which is far less than its average concentration during the wet season, and this can be majorly due to the overland runoff of organics into the source, Kangimi reservoir, during the season. The average concentration of nitrate in the treated water ready for distribution is 2.05 mg/l, which is far below the permissible recommended limits of nitrate in water according to Nigeria standard for drinking water quality, 2007 and WHO drinking water standard, 1993. As such, the treated water is safe for

consumption in terms of nitrate concentration especially because of infants who are at higher risk to blue babies syndrome.

Table 4.34: The Nitrate in mg/l of water through the different units in KNWW treatment plant

Sampling Dates	RWT	AWT	CWT	GSWT	BSWT	GFWT	BFWT	CT/TW	WHO 1993	NIG 2007
06/10/2015	6.3	3	3	2.8	2.8	2.3	3.1	3	50	50
13/10/2015	5.8	3.6	3.2	2.6	4.9	2.1	2.9	3.8		
20/10/2015	7.4	2.3	2.1	1.4	1.1	1	1.3	0.8		
27/10/2015	4.5	1.5	1.4	0	0	1.2	1.4	1.5		
03/11/2015	5.6	3.5	3.1	2.6	4.9	2.4	3.1	3.2		
10/11/2015	6.5	2.3	1.9	1	1	0	0	0		
17/11/2015	4.9	0.9	1	0	0	1.5	1.5	2		
24/11/2015	5	2.4	2	1	1.3	0.7	1.5	2.1		
Average	**5.75**	**2.4375**	**2.2125**	**1.425**	**2**	**1.4**	**1.85**	**2.05**		

RWT – Raw Water Tank, AWT – Aerated Water Tank, CWT – Coagulated Water Tank, GSWT – Good Sedimentation Water Tank, BSWT – Bad Sedimentation Water Tank, GFWT – Good Filtration Water Tank, BFWT – Bad Filtration Water Tank, CT/TW – Contact Tank/Treated Water, WHO – World Health organisation drinking water standard, NIG – Nigeria drinking water standard.

4.17.3.3 Chloride

Chloride concentrations along the treatment processes and unit operations are shown in Table 4.35. Chlorides are responsible for brackish taste in water and are an indicator of sewage pollution because of the chloride content of urine (Tebutt, 1998). They also affect the solubility of oxygen in water thereby reducing the saturation of dissolved oxygen concentration. The average chloride concentration of the treated water ready for distribution is 5.93375 mg/l which is far below the permissible recommended limits for Nigeria standard of drinking water quality, 2007 and WHO drinking water standard, 1993.

Table 4.35: Shows the Chloride in mg/l of water through the different units in KNWW treatment plant

Sampling Dates	RWT	AWT	CWT	GSWT	BSWT	GFWT	BFWT	CT/TW	WHO 1993	NIG 2007
06/10/2015	6.49	5.49	8.67	6.54	9.66	4.78	7.25	6.88	250	250
13/10/2015	5.04	3.99	6.43	4.5	7.68	3.99	5.44	4.94		
20/10/2015	8.24	5.34	8.77	3.99	9.69	3.99	7.58	5.49		
27/10/2015	12.04	11.99	10.4	6.48	7.8	4.3	7.8	6.84		
03/11/2015	7.99	5.08	5.48	5.83	6.49	7.49	6.99	5.33		
10/11/2015	4.44	4.09	9.86	5.35	10.49	4.45	8.49	6.86		
17/11/2015	6.49	4.99	5.48	5.99	6.49	7.49	6.99	5.49		
24/11/2015	6.5	5.47	7.54	5.34	10.49	3.92	7.83	5.64		
Average	**7.15375**	**5.805**	**7.82875**	**5.5025**	**8.59875**	**5.05125**	**7.29625**	**5.93375**		

RWT – Raw Water Tank, AWT – Aerated Water Tank, CWT – Coagulated Water Tank, GSWT – Good Sedimentation Water Tank, BSWT – Bad Sedimentation Water Tank, GFWT – Good Filtration Water Tank, BFWT – Bad Filtration Water Tank, CT/TW – Contact Tank/Treated Water, WHO – World Health organisation drinking water standard, NIG – Nigeria drinking water standard.

4.17.3.4 Alkalinity

The alkalinities of the raw water through the treatment plant are presented in Table 4.36. The average concentration of alkalinic ions in the treated water ready for distribution is 13.6875 as against its raw water concentration of 21.75. The decrease in the alkalinity of the raw water was as a result of the application of the coagulant which is impact the alkalinity of the water as a result of the chemical hydrolysis of the coagulant thereby neutralizing the presences of some alkaline components.

Table 4.36: Shows the Alkalinity in mg/l of water through the different units in KNWW treatment plant

Sampling Dates	RWT	AWT	CWT	GSWT	BSWT	GFWT	BFWT	CT/TW	WHO 1993	NIG 2007
06/10/2015	33	32	10	19	17	10	14	16	-	-
13/10/2015	32	26	9	12	7	17	10	15		
20/10/2015	26	24	13	16	17	18	12	18		
27/10/2015	34	34	20	26	19	23	24	24		
03/11/2015	30	28	15	18	14	19	13	18		
10/11/2015	36	29	17	23	20	26	24	25		
17/11/2015	34	38	21	24	27	29	30	28		
24/11/2015	35	33	19	25	25	28	32	30		
Average	**32.5**	**30.5**	**15.5**	**20.375**	**18.25**	**21.25**	**19.875**	**21.75**		

RWT – Raw Water Tank, AWT – Aerated Water Tank, CWT – Coagulated Water Tank, GSWT – Good Sedimentation Water Tank, BSWT – Bad Sedimentation Water Tank, GFWT – Good Filtration Water Tank, BFWT – Bad Filtration Water Tank, CT/TW – Contact Tank/Treated Water, WHO – World Health organisation drinking water standard, NIG – Nigeria drinking water standard.

4.17.3.5 Acidity

The acidity of the raw water through the treatment plant is presented in Table 4.37. The average concentration of acidic ions in the treated water ready for distribution is 17.25 mg/l as against its raw water concentration of 15.6 mg/l. The increase in the acidity of the water was as a result of the application of the coagulant in CWT which impacted drastically by increasing the production of the hydrogen ions via the chemical hydrolysis of the coagulant, producing more hydrogen ions than the alkaline component hydroxide ions, thereby speedily neutralizing the presences of some of the alkaline components.

Table 4.37: Shows the Acidity in mg/l of water through the different units in KNWW treatment plant

Sampling Dates	RWT	AWT	CWT	GSWT	BSWT	GFWT	BFWT	CT/TW	WHO 1993	NIG 2007
06/10/2015	14.5	13.5	44.4	23.4	19	21.5	24	20.5	-	-
13/10/2015	17	11.5	39	10	12.5	12.5	15	12.5		
20/10/2015	15	18	42.5	12	16.5	16.5	18	17		
27/10/2015	16.5	11	46	14	17	16	19	20		
03/11/2015	12	8	34.6	9	11	14	17	15		
10/11/2015	17.5	14.5	41.5	16	18	15	20	17		
17/11/2015	14	11	40.8	15.6	12	19	21	18		
24/11/2015	18.3	12.6	39.8	15.5	16	18	13	18		
Average	**15.6**	**12.5125**	**41.075**	**14.4375**	**15.25**	**16.5625**	**18.375**	**17.25**		

RWT – Raw Water Tank, AWT – Aerated Water Tank, CWT – Coagulated Water Tank, GSWT – Good Sedimentation Water Tank, BSWT – Bad Sedimentation Water Tank, GFWT – Good Filtration Water Tank, BFWT – Bad Filtration Water Tank, CT/TW – Contact Tank/Treated Water, WHO – World Health organisation drinking water standard, NIG – Nigeria drinking water standard.

4.17.3.6 Hardness

The hardness of the raw water through the treatment plant is presented in Table 4.38. This is the property of water which prevents lather formation with soap and produces scale in hot water system. The result shows that the raw water hardness had an average of 171.2 mg/l, but at the effective sedimentation operations, it decreased to 102.6625 mg/l as a result of precipitation of the metallic ions responsible for the hardness of the water due to flocculation. The average hardness of the treated water in contact tank is 127.575 mg/l, which is within the recommended permissible limits for Nigeria standard of drinking water quality, 2007 and WHO drinking water standard, 1993.

Table 4.38: Shows the hardness in mg/l of water through the different units in KNWW treatment plant

Sampling Dates	RWT	AWT	CWT	GSWT	BSWT	GFWT	BFWT	CT/TW	WHO 1993	NIG 2007
06/10/2015	181.8	101	121.2	101	131.3	111.1	141.4	121.2	150	150
13/10/2015	151.5	127.9	114.8	88.4	104.7	98.5	143.2	121.4		
20/10/2015	178.4	161.4	161.4	96.2	141.4	101.9	136.2	119.5		
27/10/2015	161.8	141.9	148.9	118.3	125.3	121.8	139.4	151.2		
03/11/2015	189.3	171	181.6	101.2	128.3	125.4	151.5	141.6		
10/11/2015	160.3	131.4	121.4	106.2	115.2	115.2	125.8	125.6		
17/11/2015	171.2	151.6	149.1	99.2	121.4	110.8	141.6	118.4		
24/11/2015	175.3	147.9	150.4	110.8	125.8	121.6	136.4	121.7		
Average	**171.2**	**141.7625**	**143.6**	**102.6625**	**124.175**	**113.2875**	**139.4375**	**127.575**		

RWT – Raw Water Tank, AWT – Aerated Water Tank, CWT – Coagulated Water Tank, GSWT – Good Sedimentation Water Tank, BSWT – Bad Sedimentation Water Tank, GFWT – Good Filtration Water Tank, BFWT – Bad Filtration Water Tank, CT/TW – Contact Tank/Treated Water, WHO – World Health organisation drinking water standard, NIG – Nigeria drinking water standard.

4.17.3.7 Residual Chlorine

The chlorine concentration of the water through the treatment plant is presented in Table 4.39. The concentration of chlorine from the result shown suggests that post chlorination of the water was not observed. The average residual chlorine in the treated water was 0.03 mg/l, which is a little far from the minimum recommended permissible limit for residual chlorine in Nigeria standard of drinking water quality, 2007 and WHO drinking water standard, 1993. Hence, recontamination of contaminant can be possible along the treatment plant and even the service pipes.

Table 4.39: Shows the Residual chlorine in mg/l of water through the different units in KNWW treatment plant

Sampling Dates	WT	AWT	CWT	GSWT	BSWT	GFWT	BFWT	CT/TW	WHO 1993	NIG 2007
06/10/2015	0.08	0.06	0.06	0.04	0.05	0.04	0.05	0.04		
13/10/2015	0.05	0.04	0.04	0.02	0.01	0.01	0.02	0.02		
20/10/2015	0.03	0.04	0.04	0.04	0.04	0.03	0.04	0.04		
27/10/2015	0.03	0.03	0.04	0.05	0.03	0.05	0.03	0.05		
03/11/2015	0.02	0.02	0.02	0.03	0.02	0.03	0.05	0.03	0.2-5	0.2-5
10/11/2015	0.03	0.04	0.04	0.02	0.02	0.02	0.02	0.02		
17/11/2015	0.06	0.04	0.03	0.03	0.02	0.02	0.03	0.02		
24/11/2015	0.02	0.02	0.02	0.01	0.01	0.02	0.01	0.02		
Average	**0.04**	**0.03625**	**0.03625**	**0.03**	**0.025**	**0.0275**	**0.03125**	**0.03**		

RWT – Raw Water Tank, AWT – Aerated Water Tank, CWT – Coagulated Water Tank, GSWT – Good Sedimentation Water Tank, BSWT – Bad Sedimentation Water Tank, GFWT – Good Filtration Water Tank, BFWT – Bad Filtration Water Tank, CT/TW – Contact Tank/Treated Water, WHO – World Health organisation drinking water standard, NIG – Nigeria drinking water standard.

4.17.3.8 Dissolved Oxygen (DO)

The concentration of dissolved oxygen in the water through the treatment plant is presented in Table 4.40. The concentration of dissolved oxygen in the water as it passed through the processes and unit operations were relatively the same in amount. However, a small decrease in amount was observed in the unit operation sections (sedimentation and filtration). This could be attributed to the reduced vibration and chemical combination of chloride with the dissolved oxygen in the water in these tanks. Oxygen is a very important element in water quality control as its presence in drinking water is desired because oxygen-saturated waters have a pleasant taste and waters lacking DO have an insipid taste (Tebbutt, 1998)

Table 4.40: Shows DO in mg/l of water through the different units in KNWW treatment plant

Sampling Dates	RWT	AWT	CWT	GSWT	BSWT	GFWT	BFWT	CT/TW	WHO 1993	NIG 2007
06/10/2015	2.8	2.6	2.3	2.3	2.5	2.5	2.4	2.5		
13/10/2015	3	3.1	2.6	2.6	2.7	2.6	2.5	2.4		
20/10/2015	2.6	2.7	2.1	2.4	3	3	2.8	2.9		
27/10/2015	2.4	3.2	2.9	2.9	2.4	2.6	2.6	2.7		
03/11/2015	3.3	3.4	2.8	2.8	3	3	3.2	3.1		
10/11/2015	3	2.8	2.2	2	2.6	2.4	2.4	2.4		
17/11/2015	3.8	3.5	3.4	3.3	3.5	3.2	3.1	3.3		
24/11/2015	2.4	2.4	2.6	2.4	2.5	2.4	2.6	2.5		
Average	**2.9125**	**2.9625**	**2.6125**	**2.5875**	**2.775**	**2.7125**	**2.7**	**2.725**		

RWT – Raw Water Tank, AWT – Aerated Water Tank, CWT – Coagulated Water Tank, GSWT – Good Sedimentation Water Tank, BSWT – Bad Sedimentation Water Tank, GFWT – Good Filtration Water Tank, BFWT – Bad Filtration Water Tank, CT/TW – Contact Tank/Treated Water, WHO – World Health organisation drinking water standard, NIG – Nigeria drinking water standard.

4.17.4 Bacteriological Count

The results of the bacteriological count of the water through the treatment plant are shown in Table 4.41. This result further shows that the residual chlorine from the treatment plant is not sufficient to destroy the bacteria in the water. The average bacteria count of the treated water is 0.875 ml per 100. This may suggest that, pre-chlorination was effective but no post-chlorination of treated water. The average bacteria count of the treated water in the contact tank is within the recommended permissible limit for Nigeria standard of drinking water quality, 2007 but not WHO drinking water standard, 1993.

Table 4.41: Shows bacteriological count in mg/l of water through the different units in KNWW treatment plant

Sampling Dates	RWT 10^3	AWT 10^3	CWT 10^3	GSWT 10^3	BSWT 10^3	GFWT 10^3	BFWT 10^3	CT/TW 10^2	WHO (1993) 10^2	NIG (2007) 10^2
06/10/2015	20	30	4	2	2	0	1	1	0	1
13/10/2015	40	40	3	2	2	2	2	2		
20/10/2015	15	60	4	5	2	1	2	1		
27/10/2015	30	40	2	2	2	0	1	1		
03/11/2015	160	15	2	2	1	0	0	0		
10/11/2015	50	100	3	4	6	1	2	1		
17/11/2015	80	110	5	2	2	1	1	1		
24/11/2015	160	70	4	3	3	0	1	0		
Average	**69.375**	**58.125**	**3.375**	**2.75**	**2.5**	**0.625**	**1.25**	**0.875**		

RWT – Raw Water Tank, AWT – Aerated Water Tank, CWT – Coagulated Water Tank, GSWT – Good Sedimentation Water Tank, BSWT – Bad Sedimentation Water Tank, GFWT – Good Filtration Water Tank, BFWT – Bad Filtration Water Tank, CT/TW – Contact Tank/Treated Water, WHO – World Health organisation drinking water standard, NIG – Nigeria drinking water standard.

4.17.5 Analysis of the chemical Parameters of KNWW Water during the dry Season using Two Ways Analysis of Variance (ANOVA)

Tests of Between-Subjects Effects

Dependent Variable: Values obtained

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Model	153772.479[a]	16	9610.780	70.611	.000
UNITS	2161.507	7	308.787	2.269	.042
CHEPAR	112138.101	8	14017.263	102.986	.000
Error	7622.073	56	136.108		
Total	161394.552	72			

a. R Squared = .953 (Adjusted R Squared = .939)

Conclusion One

A two-way ANOVA was conducted that examined the effect of chemical parameters and units of water in KNWW treatment plant. There was a statistically significant difference between the chemical parameters F (8,56) = 2.269, *p = 0.0005*

Since significant value of the chemical parameters (p) = 0.000 < α = 0.05, we reject H_0 and conclude that there are significant differences in the means chemical Parameters of KNWW water during wet season. Hence, this necessitate for further study.

Conclusion Two

Simple main effects analysis showed that there were also differences between the units of water in KNWW Treatment Plant

Since significant value of the units in KNWW (p) = 0.042 > α = 0.05, we also reject H_0 and conclude that there were statistically significant differences in the means Units of KNWW water during dry season.

Multiple Comparisons

Dependent Variable: Values obtained
Tukey HSD

(I) PHYSICAL PARAMETERS	(J) PHYSICAL PARAMETERS	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
pH	NITRATE	4.87656	5.833276	.995	-13.94192	23.69505
	CHLORIDE	.62094	5.833276	1.000	-18.19755	19.43942
	ALKALINITY	-15.23281	5.833276	.205	-34.05130	3.58567
	ACIDITY	-11.61581	5.833276	.556	-30.43430	7.20267
	HARDNESS	-125.69532*	5.833276	.000	-144.51381	-106.87684
	RESIDUAL CHLORINE	7.23512	5.833276	.944	-11.58336	26.05361
	DISSOLVED OXYGEN	4.51856	5.833276	.997	-14.29992	23.33705
	BACTERIOLOGY COUNT	-10.03219	5.833276	.732	-28.85067	8.78630
NITRATE	pH	-4.87656	5.833276	.995	-23.69505	13.94192
	CHLORIDE	-4.25563	5.833276	.998	-23.07411	14.56286
	ALKALINITY	-20.10938*	5.833276	.028	-38.92786	-1.29089
	ACIDITY	-16.49238	5.833276	.130	-35.31086	2.32611
	HARDNESS	-130.57189*	5.833276	.000	-149.39037	-111.75340
	RESIDUAL CHLORINE	2.35856	5.833276	1.000	-16.45992	21.17705

	DISSOLVED OXYGEN	-.35800	5.833276	1.000	-19.17648	18.46048
	BACTERIOLOGY COUNT	-14.90875	5.833276	.229	-33.72723	3.90973
	pH	-.62094	5.833276	1.000	-19.43942	18.19755
	NITRATE	4.25563	5.833276	.998	-14.56286	23.07411
	ALKALINITY	-15.85375	5.833276	.165	-34.67223	2.96473
	ACIDITY	-12.23675	5.833276	.485	-31.05523	6.58173
	HARDNESS	-126.31626*	5.833276	.000	-145.13475	-107.49778
CHLORIDE	RESIDUAL CHLORINE	6.61419	5.833276	.966	-12.20430	25.43267
	DISSOLVED OXYGEN	3.89763	5.833276	.999	-14.92086	22.71611
	BACTERIOLOGY COUNT	-10.65312	5.833276	.665	-29.47161	8.16536
	pH	15.23281	5.833276	.205	-3.58567	34.05130
	NITRATE	20.10938*	5.833276	.028	1.29089	38.92786
	CHLORIDE	15.85375	5.833276	.165	-2.96473	34.67223
	ACIDITY	3.61700	5.833276	.999	-15.20148	22.43548
	HARDNESS	-110.46251*	5.833276	.000	-129.28100	-91.64403
ALKALINITY	RESIDUAL CHLORINE	22.46794*	5.833276	.009	3.64945	41.28642
	DISSOLVED OXYGEN	19.75138*	5.833276	.033	.93289	38.56986
	BACTERIOLOGY COUNT	5.20063	5.833276	.993	-13.61786	24.01911
	pH	11.61581	5.833276	.556	-7.20267	30.43430
	NITRATE	16.49238	5.833276	.130	-2.32611	35.31086
	CHLORIDE	12.23675	5.833276	.485	-6.58173	31.05523
	ALKALINITY	-3.61700	5.833276	.999	-22.43548	15.20148
	HARDNESS	-114.07951*	5.833276	.000	-132.89800	-95.26103
ACIDITY	RESIDUAL CHLORINE	18.85094*	5.833276	.049	.03245	37.66942
	DISSOLVED OXYGEN	16.13438	5.833276	.149	-2.68411	34.95286
	BACTERIOLOGY COUNT	1.58363	5.833276	1.000	-17.23486	20.40211
	pH	125.69532*	5.833276	.000	106.87684	144.51381
	NITRATE	130.57189*	5.833276	.000	111.75340	149.39037
HARDNESS	CHLORIDE	126.31626*	5.833276	.000	107.49778	145.13475
	ALKALINITY	110.46251*	5.833276	.000	91.64403	129.28100
	ACIDITY	114.07951*	5.833276	.000	95.26103	132.89800

	RESIDUAL CHLORINE	132.93045*	5.833276	.000	114.11197	151.74893
	DISSOLVED OXYGEN	130.21389*	5.833276	.000	111.39540	149.03237
	BACTERIOLOGY COUNT	115.66314*	5.833276	.000	96.84465	134.48162
	pH	-7.23512	5.833276	.944	-26.05361	11.58336
	NITRATE	-2.35856	5.833276	1.000	-21.17705	16.45992
	CHLORIDE	-6.61419	5.833276	.966	-25.43267	12.20430
	ALKALINITY	-22.46794*	5.833276	.009	-41.28642	-3.64945
RESIDUAL	ACIDITY	-18.85094*	5.833276	.049	-37.66942	-.03245
CHLORINE	HARDNESS	-132.93045*	5.833276	.000	-151.74893	-114.11197
	DISSOLVED OXYGEN	-2.71656	5.833276	1.000	-21.53505	16.10192
	BACTERIOLOGY COUNT	-17.26731	5.833276	.096	-36.08580	1.55117
	pH	-4.51856	5.833276	.997	-23.33705	14.29992
	NITRATE	.35800	5.833276	1.000	-18.46048	19.17648
	CHLORIDE	-3.89763	5.833276	.999	-22.71611	14.92086
	ALKALINITY	-19.75138*	5.833276	.033	-38.56986	-.93289
DISSOLVED	ACIDITY	-16.13438	5.833276	.149	-34.95286	2.68411
OXYGEN	HARDNESS	-130.21389*	5.833276	.000	-149.03237	-111.39540
	RESIDUAL CHLORINE	2.71656	5.833276	1.000	-16.10192	21.53505
	BACTERIOLOGY COUNT	-14.55075	5.833276	.257	-33.36923	4.26773
	pH	10.03219	5.833276	.732	-8.78630	28.85067
	NITRATE	14.90875	5.833276	.229	-3.90973	33.72723
	CHLORIDE	10.65312	5.833276	.665	-8.16536	29.47161
	ALKALINITY	-5.20063	5.833276	.993	-24.01911	13.61786
BACTERIOLOGY	ACIDITY	-1.58363	5.833276	1.000	-20.40211	17.23486
COUNT	HARDNESS	-115.66314*	5.833276	.000	-134.48162	-96.84465
	RESIDUAL CHLORINE	17.26731	5.833276	.096	-1.55117	36.08580
	DISSOLVED OXYGEN	14.55075	5.833276	.257	-4.26773	33.36923

Based on observed means.

The error term is Mean Square (Error) = 136.108.

*. The mean difference is significant at the .05 level.

Multiple Comparisons

Dependent Variable: Values obtained

Tukey HSD

(I) UNITS IN KNWW TREATMENT PLANTS	(J) UNITS IN KNWW TREATMENT PLANTS	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
RWT	AWT	5.60854	5.499666	.969	-11.70596	22.92305
	CWT	9.86017	5.499666	.627	-7.45434	27.17467
	GSWT	17.28097	5.499666	.051	-.03353	34.59547
	BSWT	14.59533	5.499666	.159	-2.71917	31.90984
	GFWT	15.97800	5.499666	.091	-1.33650	33.29250
	BRWT	12.67269	5.499666	.310	-4.64181	29.98720
	CT/TW	14.06172	5.499666	.194	-3.25278	31.37622
AWT	RWT	-5.60854	5.499666	.969	-22.92305	11.70596
	CWT	4.25162	5.499666	.994	-13.06288	21.56612
	GSWT	11.67243	5.499666	.414	-5.64207	28.98693
	BSWT	8.98679	5.499666	.728	-8.32771	26.30129
	GFWT	10.36946	5.499666	.566	-6.94505	27.68396
	BRWT	7.06415	5.499666	.901	-10.25035	24.37865
	CT/TW	8.45318	5.499666	.784	-8.86132	25.76768
CWT	RWT	-9.86017	5.499666	.627	-27.17467	7.45434
	AWT	-4.25162	5.499666	.994	-21.56612	13.06288
	GSWT	7.42081	5.499666	.876	-9.89370	24.73531
	BSWT	4.73517	5.499666	.988	-12.57934	22.04967
	GFWT	6.11783	5.499666	.951	-11.19667	23.43234
	BRWT	2.81253	5.499666	1.000	-14.50197	20.12703
	CT/TW	4.20156	5.499666	.994	-13.11295	21.51606
GSWT	RWT	-17.28097	5.499666	.051	-34.59547	.03353
	AWT	-11.67243	5.499666	.414	-28.98693	5.64207
	CWT	-7.42081	5.499666	.876	-24.73531	9.89370
	BSWT	-2.68564	5.499666	1.000	-20.00014	14.62886
	GFWT	-1.30297	5.499666	1.000	-18.61747	16.01153
	BRWT	-4.60828	5.499666	.990	-21.92278	12.70622
	CT/TW	-3.21925	5.499666	.999	-20.53375	14.09525
BSWT	RWT	-14.59533	5.499666	.159	-31.90984	2.71917
	AWT	-8.98679	5.499666	.728	-26.30129	8.32771
	CWT	-4.73517	5.499666	.988	-22.04967	12.57934
	GSWT	2.68564	5.499666	1.000	-14.62886	20.00014
	GFWT	1.38267	5.499666	1.000	-15.93184	18.69717
	BRWT	-1.92264	5.499666	1.000	-19.23714	15.39186
	CT/TW	-.53361	5.499666	1.000	-17.84811	16.78089
GFWT	RWT	-15.97800	5.499666	.091	-33.29250	1.33650
	AWT	-10.36946	5.499666	.566	-27.68396	6.94505

	CWT	-6.11783	5.499666	.951	-23.43234	11.19667
	GSWT	1.30297	5.499666	1.000	-16.01153	18.61747
	BSWT	-1.38267	5.499666	1.000	-18.69717	15.93184
	BRWT	-3.30531	5.499666	.999	-20.61981	14.00920
	CT/TW	-1.91628	5.499666	1.000	-19.23078	15.39822
	RWT	-12.67269	5.499666	.310	-29.98720	4.64181
	AWT	-7.06415	5.499666	.901	-24.37865	10.25035
	CWT	-2.81253	5.499666	1.000	-20.12703	14.50197
BRWT	GSWT	4.60828	5.499666	.990	-12.70622	21.92278
	BSWT	1.92264	5.499666	1.000	-15.39186	19.23714
	GFWT	3.30531	5.499666	.999	-14.00920	20.61981
	CT/TW	1.38903	5.499666	1.000	-15.92547	18.70353
	RWT	-14.06172	5.499666	.194	-31.37622	3.25278
	AWT	-8.45318	5.499666	.784	-25.76768	8.86132
	CWT	-4.20156	5.499666	.994	-21.51606	13.11295
CT/TW	GSWT	3.21925	5.499666	.999	-14.09525	20.53375
	BSWT	.53361	5.499666	1.000	-16.78089	17.84811
	GFWT	1.91628	5.499666	1.000	-15.39822	19.23078
	BRWT	-1.38903	5.499666	1.000	-18.70353	15.92547

Based on observed means.
The error term is Mean Square (Error) = 136.108.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

Based on the findings, the following conclusions are made

5.1 Conclusions

1. A prime cause for Kaduna North Water Works (KNWWs) inability to meet the required level of service is mainly due to poor operation and maintenance practice (O and M), which leads to high water losses in the production processes, capacity losses of pumps and affects total production significantly, unavailability of spare parts and tools, lack of standby equipments to augment, fluctuation in power supply, These losses affect of course booster stations and reservoirs as less water is distributed to the consumers ,lack of operation, maintenance and repair manuals are not available for staff, finally it is understood that the amount of water pumped in from the intake isn't the amount pumped to the public this is due to excessive backwashing and dislodging due to the manually operated plant at present, since it lacks functional instrumentation, controls and bulk metering.

2. Assessment shows that day-to-day management of these water schemes is often complicated by problems at the state level: inadequate or ambiguous legislation, poor allocation and or duplication of responsibilities among ministries and different levels of government and excessive number of poorly-paid, delays in release of remunerations and de-motivated staff. Problems of the intake and power cuts create changing hydraulically loads and so affect retention, available treatment time for the water in the treatment steps.

3. A simple empirical tool for assessing the performance of Kaduna North Water Works (KNWWs) has been applied in the study by using some evaluation criteria from four key performance areas namely; Operational, Financial, Institution and human

resources capacity. The approach developed is referred to as Service Performance Evaluation Metric (SPEM).

4. The quality of water delivered to the studied area was observed to change with season. The water quality was perceived better in dry season than in wet season due to faulty operation and processing units which cannot treat raw water efficiently due to high turbidity of the raw water as a result of overland flow during (the wet season.

5.2 Recommendations

1. **Additional Water Treatment plant;** There is a need for the service reservoirs to maintain a constant pressure head in order to continually meet the minimum pressure head requirement for low and high pressure zones within the study areas, most especially during the peak hour time, this can be achieved if an additional treatment plant is constructed to augment ,rather than the present production during day and night while direct pumping takes place in the early hours of the morning
2. **Clear water tank;** proposed construction of a sump in the clear water tank will aid the water supply efficiency via the avoidance of excessive wastage of dead storage which constitute 25% of treated water usually impounded in the clear water tank.
3. **Sedimentation Tank;** Due to non working pulsators and de-sludging system the practice of permanent de-sludging is often carried out based on observation and experience. The load to the sedimentation tanks and retention time has to be as constant as possible and in accordance to the design operational specifications. The shock loads and the variation in quantities need to be avoided. The distribution to the retention tanks has to be equal. The water discharged from the retention needs to be equal and constant.

4. **Metering:** The inflow quantity but also distribution of the water per treatment step and finally outflow quantity has to be known at every time and recorded. Quantity measurements and pump test will be necessary.
5. **Filter Bed;** Penstocks are not working or closing correctly resulting to continuous drainage of water from the filter surface to the drain, non functional control resulting to high water losses in the filter. The filter bed reinforced concrete screened slabs must be re-casted and all screens reinstalled to enable the operational unit to function optimally. This is true for the new as well as for the old water works. Both have problems with the filter beds (broken filter beds, bad and missing sand) and backwash installations (Valves).
6. **Dosing pumps;** The dosing of the chemicals has to be based on laboratory test (flocculation) and working constantly. Sufficient chemicals have to be available all time.
7. **Instrumentation and metering;** The dislodging system has to be operated in an optimized schedule, such that, the settlement processes are not disturbed as much as possible. The need for mechanism to detect faults and the efficiency of the dislodging operation at periodic intervals will be necessary.
8. **Intake pump;** Proposed construction of stop locks and a reinforced concrete dwarf retaining wall not short of 2 meter high be constructed close to the intake works, so as to allow for opening up to aid flushing of accumulated silted sand particles and to also prevent bed load from drifting towards the installed intake pump presently observed to be often under repairs due to clogging of impellers.
9. **Operation, Maintenance;** The electro mechanical pumps installed are all imported and have their operational guidelines for the relays often being affected via tripping off at times of high and low current, all of which has a preset time for them to

resume operation, but this time preset are often not abided by, as pressure mounts on the technical staff by powers that may be for lack of water supply as such the pumps are often hard started to continue operations, they lack operation and maintenance schedule in the form of preventive maintenance, as such the condition of the plant reflects the situation i.e. corrective maintain ace is applied thereby affecting the service delivery,

10. **Manuals and documentation;** The technical staff and operators do not take the formal operational concept guideline or instruction seriously may be due to over stay in a unit. The operational concepts are controlled depending on operator's judgment and sometimes uncontrolled.

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APPENDICES

APPENDIX A

Respondents Characteristics from Questionnaire

Table A1: Gender and age distribution of respondents

Ages (Years)	Male	Percentage (%)	Female	Percentage (%)
Below 25	56	22.13	79	53.74
25 - 40	161	63.64	48	32.65
Above 40	36	14.23	20	13.61
Total	**253**	**100**	**147**	**100**

Table A2: Respondents of Educational Level

Educational Level	Frequency	Percentage (%)
Tertiary	88	22.00
Secondary	186	46.50
Basic	103	25.75
None	23	5.75
Total	**400**	**100**

Table A3: Hours of flow in a day

Hours in a day/Community	0 - 8hrs GMT	(%)	8 - 16hrs GMT	(%)	16 - 24hrs GMT	(%)
Airport	27	54	15	30	8	16
NDA	26	52	13	26	11	22
Lagard Hall	14	28	28	56	8	16
Mando	19	38	21	42	10	20
State House Kawo	29	58	16	32	5	10
Tudun Wada	28	56	18	36	4	8
Rigasa	27	54	16	32	7	14
Ungwan Muazu	28	56	20	40	2	4
Total	**198**	**49.5**	**147**	**36.75**	**55**	**13.75**

Table A4: Consumers Assessment on Satisfaction of flow Condition

Assessment/Community	Excellent	(%)	Good	(%)	Fair	(%)	Poor	(%)
Airport	8	16	12	24	16	32	14	28
NDA	10	20	21	42	14	28	5	10
Lagard Hall	13	26	17	34	14	28	6	12
Mando	4	8	13	26	18	36	15	30
State House Kawo	16	32	21	42	10	20	3	6
Tudun Wada	7	14	23	46	9	18	11	22
Rigasa	3	6	8	16	25	50	14	28
Ungwan Muazu	4	8	6	12	32	64	8	16
Total	**65**	**16**	**121**	**30**	**138**	**35**	**76**	**19**

Table A5: Consumers Perception on Taste of water

Assessment/Community	Excellent	(%)	Good	(%)	Fair	(%)	Poor	(%)
Airport	3	6	18	36	16	32	13	26
NDA	6	12	16	32	23	46	5	10
Lagard Hall	8	16	9	18	26	52	7	14
Mando	12	24	27	54	10	20	1	20
State House Kawo	23	46	19	38	4	8	4	8
T/Wada	3	6	26	52	15	34	6	12
Rigasa	3	6	14	28	28	56	5	10
Ungwan Muazu	4	8	16	32	24	48	6	12
Total	**62**	**15.5**	**145**	**36.25**	**146**	**36.5**	**47**	**11.75**

Table A6: Consumers Perception on smell of water

Assessment/Community	Excellent	(%)	Good	(%)	Fair	(%)	Poor	(%)
Airport	11	22	28	56	7	14	4	8
NDA	6	12	30	60	8	16	6	12
Lagard Hall	9	18	27	54	10	20	4	8
Mando	16	32	24	48	8	16	2	4
State House Kawo	7	14	26	52	15	30	2	4
Tudun Wada	12	24	23	46	9	18	6	12
Rigasa	14	28	31	62	4	8	1	2
Ungwan Muazu	10	20	23	46	10	20	7	14
Total	**85**	**21**	**212**	**53**	**71**	**18**	**32**	**8**

Table A7: Consumers Perception on Colour of water

Assessment/Community	Excellent	(%)	Good	(%)	Fair	(%)	Poor	(%)
Airport	6	12	21	42	16	32	7	14
NDA	9	18	19	38	21	42	1	2
Lagard Hall	5	10	15	30	25	50	5	10
Mando	8	16	14	28	26	52	2	4
State House Kawo	11	22	29	58	8	16	2	4
Tudun Wada	2	4	13	26	28	56	7	14
Rigasa	3	6	6	12	27	54	14	28
Ungwan Muazu	1	2	5	10	32	64	12	21
Total	**45**	**11.25**	**122**	**30.5**	**183**	**45.75**	**50**	**12.5**

Table A8: Consumers Perception about billing

Assessment/Community	Low	Average	High	very high
Airport	3	28	10	9
NDA	4	27	15	4
Lagard Hall	9	18	22	1
Mando	11	29	8	2
State House Kawo	4	31	9	6
Tudun Wada	8	16	20	6
Rigasa	7	24	15	4
Ungwan Muazu	6	26	12	6
Total	**52**	**199**	**111**	**38**
Percentage (%)	**13**	**49.75**	**27.75**	**9.5**

Table A9: Mode of complaint

Community/Mode of Complaint	Phone	Percentage (%)	Personal Presence	Percentage (%)
Airport	21	42	29	58
NDA	12	24	38	76
Lagard Hall	16	32	34	68
Mando	17	34	33	66
State House Kawo	23	46	27	54
Tudun Wada	16	32	34	68
Rigasa	6	12	44	88
Ungwan Muazu	13	26	37	64
Total	**124**	**31**	**276**	**69**

Table A10: Customer Satisfaction

Community/Responses	Yes	(%)	No	(%)
Airport	20	40	30	60
NDA	16	32	34	68
Lagard Hall	22	44	28	56
Mando	16	32	34	68
State House Kawo	32	64	18	37
Tudun Wada	14	28	36	72
Rigasa	8	16	42	84
Ungwan Muazu	21	42	29	58
Total	**149**	**37.25**	**251**	**62.75**

Table A11: Consumers Assessment on Notification of Service Interruption

Community/Responses	Excellent	(%)	Good	(%)	Fair	(%)	Poor	(%)
Airport	3	6	17	34	26	52	4	8
NDA	5	10	21	42	24	48	-	-
Lagard Hall	9	18	19	38	20	40	2	4
Mando	4	8	10	20	24	48	12	24
State House Kawo	16	32	24	48	8	16	2	4
Tudun Wada	7	14	18	36	20	40	5	10
Rigasa	11	22	17	34	12	24	10	20
Ungwan Muazu	6	12	19	38	19	38	6	12
Total	**61**	**15.25**	**145**	**36.25**	**153**	**38.25**	**41**	**10.25**

Table 4.12: Consumers Assessment on the meter Readers

Community/Responses	Good	(%)	Fair	(%)	Poor	(%)
Airport	21	42	19	38	10	20
NDA	24	48	21	42	5	10
Lagard Hall	5	10	16	32	29	58
Mando	10	20	19	38	21	42
State House Kawo	22	44	21	42	7	14
Tudun Wada	8	16	21	42	21	42
Rigasa	4	8	30	60	16	32
Ungwan Muazu	16	32	19	38	15	30
Total	**110**	**27.5**	**166**	**41.5**	**124**	**31**

APPENDIX B

Analyses of Responses by the Kaduna North Water Works (KNWWs) Staff

Table B1: Gender and age distribution of KNWWs Staff

Ages (Years)	Male	Percentage (%)	Female	Percentage (%)
18 - 25	26	37	6	24
26 - 35	29	41	13	52
36 - 45	9	13	4	16
Above 45	6	9	2	8
Total	**70**	**100**	**25**	**100**

Table B2: Educational Levels of Staffs

Educational Level	Male	Percentage (%)	Female	Percentage (%)
Secondary / Tech.	21	28	8	42
Diploma	33	43	6	32
Tertiary	22	29	5	26
Total	**76**	**100**	**19**	**100**

APPENDIX C

QUESTIONNAIRE FOR RESIDENTS

As part of the requirement for the award of Maters in Science at Ahmadu Bello University Zaria in the Department of Water Resources and Environmental Engineering faculty of Engineering, I **Abubakar Yebom Musa** of Department of Water Resources and Environmental Engineering with registration number **P13EGWR8028** conducting a dissertation study on the topic "**Assessment of the performance of water supply Service in Kaduna North water works**".

I would be very grateful if you could support this study by completing this questionnaire and your candid response will be very much appreciated.

You are assured of the anonymity of your identity and confidentiality of your response.

Kindly tick **(√)** where appropriate and write your response where applicable.

Section A: Socio-Demographic characteristics of respondents

1. Sex: (a) Male ( ) (b) Female ( )

2. Age (years) (a) 18-25 ( ) (b) 26-35 ( ) (c) 36-45 ( ) (d) 46 and above ( )

3. What is your highest level of education? Basic ( ) Secondary/Tech. ( ) University/Tertiary ( ) None ( ) Please specify

Section B: Flow Condition

1 What is your household size (how many are you in your household)?

(a) 1-3 ( ) (b) 4-6 ( ) (c) 7-9 ( ) (d) 10 and above ( )

2 How many days in the week do you get water?

(a) 1-2days ( ) (b) 3-4days ( ) (c) 5-6days ( ) (d) Weekly ( )

3 How many hours in a day do you receive water?

(a) Less than 4hrs (b) Less than 8 hrs ( ) (b) Between 8-16hrs ( )

(c) Between 16-24hrs ( )

4 On the average how many buckets (34 cm size/ 4 gallons) of water do you need for your household per day? (a) 4 ( ) (b) 8 ( ) (c) 12 ( ) (d) more than 12 ( )

5 Is the water you fetch sufficient to meet your household requirements?

(a) Yes ( ) (b) No ( )

6 Do you have any other source of water? (a) Yes ( ) (b) No ( )

7 If yes, what is the source?

(a) Well/Borehole ( ) (b) Rainwater ( ) (c) Streams/Lake ( ) (d) Private providers ( ).

Section C: Quality of Water

8 What is your impression about the physical water quality - taste?

(a) Excellent ( ) (b) Good ( ) (c) Fair ( ) (d) Poor ( )

9 What is your impression about the physical water quality - smell?

(a) Excellent ( ) (b) Good ( ) (c) Fair ( ) (d) Poor ( )

10 What is your impression about the physical water quality - colour?

(a) Excellent ( ) (b) Good ( ) (c) Fair ( ) (d) Poor ( )

Section D: Billing

11 Is your water account metered? (a) Yes ( ) (b) No ( )

12 Is your meter read regularly? (a)Yes ( ) (b) No ( )

13 Are Bills received regularly? (a) Yes ( ) (b) No ( )

14 How much do you pay on the average for water per month? (In Naira)
(a) 500 - 1000 ( ) (b) 1000 - 1500 ( ) (c) 1500 - 2000 ( ) (d) Above 2000 ( )

15 What is your impression about the water bill? (a) Low ( ) (b) Average ( ) (c) High ( ) (d) Very high ( )

16 Do you think water bills should be increased in order to improve water supply and delivery services? (a) Yes ( ) (b) No ( )

Section E: Customer Care

17 Are you satisfied with KNWW water services? (a) Yes ( ) (b) No ( )

18 What is your opinion on KNWW billing staff attitude to customers?
(a) Excellent ( ) (b) Good ( ) (c) Fair ( ) (d) Poor ( )

19 Have you ever made a complaint to KNWW? (a) Yes ( ) (b) No ( )

20 If yes, what was your mode of communication?
(a) Phone ( ) (b) Physical presence ( ) (c) Through PURC ( )

21 Did you get a satisfactory response? (a)Yes ( ) (b) No ( )

22 How will you grade KNWW's response to a complaint?

(a) Excellent ( ) (b) Good ( ) (c) Fair ( ) (d) Poor ( )

23 Are you notified before service is interrupted? (a) Yes ( ) (b) No ( )

24 What is your impression of KSWW" s notification to service interruption?

(a) Excellent ( ) (b) Good ( ) (c) Fair ( ) (d) Poor ( )

25 To what extent are you satisfied with the services of KNWW?

(a) Very extensive ( ) (b) Extensive ( ) (c) Less extensive ( ) (d) Not at all ( )

Section F: Effects of Inadequate Water Supply

26 What will you say about the following issues of water supply and delivery in the Kaduna North Municipality? Tick (√) as appropriate in the columns under: (a) Severe problem; (b) Minor problem; (c) Not a problem and (d) Don't know in the table below.

Issues	**Severe problem**	**Minor problem**	**Not a problem**	**Don't know**
1. Water shortages slows down domestic and commercial activities				
2. High water charges from water vendors				
3. Too much time wasted in search of water				
4. Long queues in fetching water leading to quarrels				
5. Reason for lateness and absenteeism in school children				
6.Children risk their lives searching for water				
7.Leads to hike in prices of food items				
8.Risk in using untreated water from streams and wells				

APPENDIX D

QUESTIONNAIRE FOR KNWW STAFFS

As part of the requirement for the award of Maters in Science at Ahmadu Bello University Zaria in the Department of Water Resources and Environmental Engineering faculty of Engineering, I **Abubakar Yebom Musa** of Department of Water Resources and Environmental Engineering with registration number **P13EGWR8028** conducting a research dissertation study on the topic "**Assessment of the performance of water supply Service in Kaduna North water works**".

I would be very grateful if you could support this study by completing this questionnaire and your candid response will be very much appreciated.

You are assured of the anonymity of your identity and confidentiality of your response.

Kindly tick **(√)** where appropriate and write your response where applicable.

Section A: Socio-Demographic characteristics of respondents

1. Sex: (a) Male ( ) (b) Female ( )

2. Age (years) (a) 18-25 ( ) (b) 26-35 ( ) (c) 36-45 ( ) (d) 46 and above ( )

3. What is your highest level of education?
Basic ( ) Secondary/Tech. ( ) University/Tertiary ( ) None ( ) Please specify

Section B: Billing

1. What is the current official tariff /price per bucket (four gallons) of water supply services in the Kaduna North Municipal? ₦……

2. Is the current tariff/price sufficient to recover costs such as operation, maintenance energy and replacement costs?

(1) Yes ( ) (2) No ( )

3. Does the level of tariff / price discourage or encourage the Kaduna North Water Work Municipal in its efforts to improve services to the urban poor?

(1) Discourages ( ) (2) Encourages ( ) (3) Don't Know ( )

4. How much do you think an average urban dweller should pay for one bucket (34cm size/4 gallons) of water?

(1) ₦10 ( ) (2) ₦20 ( ) (3) ₦30 ( ) (4) ₦40 ( ) (5) ₦50 ( ) (6) ₦60 ( )

Section C: Effects of Inadequate Water Supply

5. What will you say about the following issues of water supply and delivery in the Kaduna North Municipality? Tick (√) as appropriate in the columns under: (a) Severe problem; (b) Minor problem; (c) Not a problem and (d) Don't know in the table below.

Issues	**Severe problem**	**Minor problem**	**Not a problem**	**Don't know**
1.Water shortage slows down domestic and commercial activities				
2. High water changes from water vendors.				
3. Too much time wasted in search of water				
4. Long queues in fetching water leading to quarrels				
5. Reason for lateness and absenteeism in school children				
6. Children risk their lives searching for water				
7. Leads to hike in prices of food items				
8. Risk in using untreated water from streams and wells				

Section D: Causes of Inadequate Water Delivery

What factors do you think account for the problems of water supply and delivery in the Kaduna North Municipality? Tick (√) as appropriate in the columns under: (a) severe problem; (b) Minor problem; (c) Not a problem and (d) Don't know in the table below.

Issues	**Severe problem**	**Minor problem**	**Not a problem**	**Don't know**
1. Perennial effects of the harmattan				
2. Frequent pipe bursts leading to leakages				
3. Power outages leading to disruption in water flow				
4. Obsolete machines at the head works				
5. Bush burning clearing the forest cover				
6. Diversion of River Kaduna for agricultural purposes				
7. Explosion in population				

Section E. Operation and Maintenance

1. What type of maintenance strategy is adopted?

(a) Planned Maintenance (b) Scheduled Maintenance (c) Condition Based Maintenance (d) Unplanned Maintenance

2. Number of pipes breakage/leakage points per Km?

(a) 3nos. (b) 5nos (c) Above 10nos (d) No breakages

3. Is the pumping station Operational? (a). Yes b). No

4. Are the intake structures functional or vandalise?

(a) Vandalized Yes (b). Vandalize No. (c). Functional Yes (d). Function No

5. Is there any fault documentation process in place? (a). Yes (b). No

6. What is the Condition of these utilities?

(a) Excellent (b) Good (c) Fair (d). Poor

7. Is the utility connected to national Grid (Power Holding Company of Nigeria? Yes or No
If No, how many generators? (a). 1 b) 2 (c). Above 2

8. Is there any plan for the future expansion of the existing facilities/utilities?

(a). Yes (b). No

9. Are spares available for maintenance? (a). Yes (b). No