EFFECT OF DISTRIBUTION SYSTEM MATERIALS ON WATER QUALITY : CASE STUDY OF CHANCHAGA WATERWORKS

BY

OKOLI, OBI RAPHAEL

MATRIC No. 2004/18404EA

DEPARTMENT OF AGRICULTURAL AND BIORESOURCES ENGINEERING

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

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

FEBRUARY, 2010

DECLARATION

I hereby declare that this project work is a record of a research work that was undertaken and writen by me. It has not been presented before for any degree, or diploma or certificate at any university or institution. Information derived from personal communications, published and unpublished work were duly referenced in the text.

18/02/10

OKOLI, OBI RAPHAEL

2004/18404EA

DATE

CERTIFICATION

This project entitled "Effect of Distribution System Materials on Water Quality: Case Study on the Chanchaga Waterworks" by Okoli Obi Raphael, meets the regulations governing the award of the degree of Bachelor of Engineering (B. ENG.) of the Federal University of Technology, Minna, and it is approved for its contribution to scientific knowledge and literary presentation.

18.02.10

Engr. Mrs. H. I. Mustapha
Project Supervisor

Date

18/02/10

Engr. Dr. A. A. Balami
Head of Department,
Agricultural and Bio-resources Engineering

Date

Engr. Prof. G. O. Chukwuma
External Examiner

10-02-10

Date

DEDICATION

This project work is dedicated to my loving parent, Mr and Mrs. Okoli.

ACKNOWLEDGEMENTS

I thank God Almighty for giving me special grace, strength and wisdom for completing this tedious but rewarding academic programme.

I wish to express my profound gratitude to my project supervisor Engr. Mrs. H. I. Mustapha for her supervision and mentoring throughout the period of this work, for making constructive criticism and useful suggestion that contributed towards the completion of this project. My sincere gratitude also goes to Dr. A. A. Balami (Head of Department), Dr. O. Chukwu, Dr. Z. D. Osunde, Engr. Adeoye, Engr. Sadiq and the entire member of staff of Agric. & Bioresources Engineering department.

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ABSTRACT

The effect of distribution system materials on water quality was evaluated by collecting and analyzing water samples from the distribution network systems of Chanchaga Waterworks in Minna, Niger state. The chemical nature of various lining, coating and sealing materials which come into direct contact with water in the distribution system was studied. The concentration of sulphate, iron and chloride in the water samples were higher than the health guidelines. Copper, magnesium, and nitrate in most samples, remain relatively stable and meets the recommended health standard. Lead, manganese and chloride concentrations in the samples from the bitumen lined reservoir were very high and above the recommended health standard. Microbial presence in the system, took the form of attached growth on the surface of the material. Leaching of additives or coatings used in the system material, leaching of original material itself, reaction of materials with chlorine or other additives as well as biotransformation of leachants by fungi, algae, or bacterial in the system appears to be responsible for the elevation of metals and other chemical substances in these water samples. The results of this study shows that the nature of distribution systems material used to convey treated water to the consumers, can modify the quality of water.

TABLES OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

ABBREVIATIONS

UNDP	United Nations Development Programme
ANSI	American National Standard Institute
NSF	National Standard Foundation
WHO	World Health Organization
NAFDAC	National Agency for Food and Drug Administration and Control
NPDWR, US	National Primary Drinking Water Regulation, United State

LIST OF APPENDICES

CHAPTER ONE

INTRODUCTION

1.1 Background

Water is vital for all life on earth. The important of water for the living beings may be judged from the fact that it is a part of life itself, since the protoplasm of most living cells contains about 80 percent water, and any substantial reduction in this percentage is disastrous. Most of the biochemical reactions that occur in the metabolism and growth of living cells involve water, and all take place in water, which is often referred to as universal solvent. Further it has been estimated that almost two-thirds of the human body is constituted of water which is required for the satisfactory performance of physiological organisms, as a circulatory fluid, as a carrier of nourishing food and for removal of the waste products from the body, (Modi, 2006).

Water is treated to achieve water quality objectives for the end users. In the case of potable water supply, water is treated to minimise risk of infectious diseases transmittal, risk of non infectious illness, and create a potable water flavour. Delivering clean water, removing wastewater and providing sanitation are three of the most basic foundations for human progress (UNDP, 2006).

1.2 Water Distribution System

A water distribution system is a network of pumps, pipelines, storage tanks/reservoir, and other appurtenances. It must deliver adequate quantities of water at pressures sufficient for operating plumbing fixtures and fire-fighting equipment, yet it must not deliver water at pressures high enough to increase the occurrence of leaks and pipeline breaks. During its passage from point of treatment to the consumer, drinking water comes into contact with a variety of materials such as metals, cements mortar or concrete, linings for pipes and reservoirs, and sealing materials. Water distribution networks are designed to meet peek demands, prevent ingress of contaminants, to maintain disinfectant residual concentrations within a locally predetermined range and to minimize the transit time/or age of the water after leaving the treatment works (Chambers et al. 2004). These networks are among any country's most precious assets. How these assets are managed and operated is critical to human development, especially in countries facing grave water security challenges (UNDP, 2006). Therefore, Good system of water treatment, distribution and monitoring is not only necessary but needed to ensure a water borne-disease free municipal water supply scheme.

To ensure delivery of a high-quality municipal potable water supply to each consumer, management of public water supply systems must be continually vigilant for any intrusion of contamination in the distribution system and the occurrence of microbial degradation. However, this job is complicated by the very nature of distribution system; a network of mains, fire hydrants, valves, auxiliary pumping, chlorination substation, storage reservoir, standpipes, and service lines.

1.3 Statement of Problem

Water bears the history of its passage through a conveyor, since it absorbs salts and organic matter from the materials with which it comes into contact, whether these be solids or gasses, (Louis, 1987). The adverse use of materials such as metals, cement mortar or concrete, linings for pipes and reservoirs and sealing materials in contact with drinking water leads to undesirable changes in the material and/or in water. These interactions which can be of an unremarkable nature, is causing a serious health problem in our society.

1.4 Objectives

1. To investigate the nature of materials used for drinking water distribution.

2. To investigate the effect of distribution system materials on water quality, and make useful recommendation to curb the deterioration of water quality due to distribution network material, if any.

1.5 Justification

Access to drinking water is measured by the number of people who have a reasonable means of getting an adequate amount of water that is safe for drinking, washing, and essential household activities. Public providers dominate water provision, accounting for more than 90% of the water delivered through networks in developing countries (UNDP, 2006). Good system of water treatment, distribution and monitoring is not only necessary but needed to ensure a water borne-disease free municipal water supply scheme. However, many publicly owned utilities are failing, combining inefficiency and ineffectiveness in system of water treatment, choice of materials for water distribution, and monitoring. Central to this, is the fact that no much recorded experience from the evaluation of existing project is available to guide selection among options at the identification and project design stage.

Therefore, this project is justified in the following;

1. To provide feedback to the water supply project itself. This enables an assessment of the project performance to be made.

2. To provide feedback to the planning process. This comes from the lessons gained from field observation and comparison of project achievement with the actual achievement of objectives. It is believed that only if representative field data are collected, analysed and directed to planners and decision makers will the disappointing record of existing water supply scheme markedly improve.

1.6 Scope of Study

The scope of study includes the following;

I. Restriction of the study to the chanchaga water works distribution system.

II. Collection and analysis of water from the treatment plant.

III. Collection and analysis of water sample from various locations in the distribution service reservoirs.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 General Review

Aqueduct to carry water was developed and built by ancient Greek and Romans during the rise to their dominance as centres of civilization. Pipe materials in these early water transport system were of stones, wood, clay, or lead. Distribution lines were simple, generally limited to a main trunk line with few dead-end branches. Water flow was dependent on gravity and the discharge from springs and from mountain stream diversions. Historically, the initial distribution network of pipes was a response to existing community needs that eventually created a legacy of problems of inadequate supply and low pressure as the population density increased. To solve the problem of increased water demand along the distribution route, reservoir storage was created. Pressure pumping to move water to far reaches of the supply lines and standpipes was incorporated to afford relief from surges of pressure in pipelines (GeldReich, 1990).

2.2 Previous Report in the Literature

There have been various reported observations on the effect of distribution system materials on water quality. The reported observations concerning situations that have been encountered in practice are presented thus;

In 1912, medical student W.Gartner reported in the Journal of Gas Lighting and Water Supply the recurrence of colony count increase in water from reservoirs which had received a new bitumen-based protective coating. On the basis of bacteriological studies, the author concluded that the protective coat had undergone leaching of substance into the water which gave rise to the multiplication of bacteria. He recommended that newly lined reservoirs should be filled with water once or twice prior to entry into service, and 'the water allowed to stand for some days in the reservoir in order to effect a leaching of the bacterial nutrients'.

In 1956, Zimmerman raised certain questions about whether colony count increase in water could be attributed to the use of polyvinylchloride (PVC) and polyethylene (PE) plastic pipes. Laboratory studies confirmed the suspicion that certain plastic materials had a growth promoting effect. The author suspected that it was not the basic polymer which was the cause of the trouble, but the low molecular weight hydrocarbons present in the products which were capable of supporting bacterial growth. Further studies were necessary in the author's opinion.

Also, Schoenen and Scholer (1985) in their own field observations on the following materials used in contact with drinking water;

- Solvent-containing bitumen lining
- Epoxy resin
- Plastic-containing cement mortar for tile linings
- PVC film for linings
- PVC coating for linings
- Polysulphide as a non-hardening sealant for expansion joints
- Styrene-modified unsaturated polyester resin incorporating glass fibre, for insulation
- Plastic-containing cement mortar for lining a drinking water pipeline
- Polyamide pipe.

They reported an intensive surface growth and colony count increase in the water. According to the authors, a microbial growth in the form of macro colonies was observed on a plasticized cement mortar lining applied to portions of an 800mm diameter water pipeline. The pipe was transporting uncontaminated water, raw unchlorinated water. They stated that the water was fed to the pipe in a bacteriologically satisfactory condition with colony counts of 0 to 5/ml. After some time, substantial colony count increases were noted in the water at the end of the pipe, far exceeding the standard. These prompted repeated flushing and chlorination of the pipeline but these measures only resulted in a temporary improvement every time. The authors remarked that even though the increased colony count ceased to recur, surface growth was still apparent at the time of most recent inspection seven and a half years after commencement of service.

However, in order to prevent deterioration of water quality, the authors recommended that only those materials should be employed which do not encourage the growth of micro-organisms by releasing organic constituents utilizable by the organisms, and that an assessment of materials for use in contact with drinking water on the basis of only proposed chemical and organoleptic tests is not satisfactory.

In 1997, Sadiq et al. on there study of the effect of distribution network materials on water quality contained in the journal of environmental science and health drew attention to increase in copper concentration in the distribution network with copper pipes from 40 locations in a community in Dhahran. They also reported that concentration of trace metals except for lead in three samples, were below the permissible limits. Also fluoride concentrations in many drinking water samples were lower than the recommended range. They observed that the PVC pipes in the network contained about 1% of lead and water passing through these pipes contained relatively higher lead concentrations. Leaching of lead from the PVC was attributed by the authors to be responsible for lead elevation in these water samples. The authors also made a particular point of the fact that iron concentrations in the water samples from the galvanized pipes were higher than those collected from non-galvanized pipes. On the basis of these observations and other related experiments in the laboratory, the authors concluded that the distribution network materials can modify water quality during transportation to the consumers.

In 2002, Abutu carried out a study on the water quality along distribution network in Minna municipal with the aim of identifying causes and points of pollution along the distribution network. He collected samples from several locations in the distribution network and subjected them to physical, chemical and bacteriological test to ascertain their portability. He stated that, traces of nitrate infiltration along the network were noticed, and that chlorine dosage allowed in the water to combat infiltration was below the required concentration, except for one incidence when it was 0.2mg/l. The author concluded that the treatment plant (i.e. chanchaga waterworks) is operating below requirement with water bacteriologically not fit for drinking. However, deterioration of water quality by organic materials or materials containing organic additives was not mentioned.

Tomboulian et al. (2004) described an investigation on the identification of possible sources and causes of taste and odour conditions associated with drinking water materials used in distribution systems. The authors evaluated information from case studies and a database from the National Sanitation Foundation (NSF), international. This database identified chemicals that had leached from drinking water system components during testing of materials under ANSI/NSF standard 61, which provides information to water utilities on potential taste-and-odour and health concerns from the use of new materials. After a sensory analysis is conducted on the drinking water samples, and the descriptor matched with category on the "Drinking water taste and odour Wheel 2000", the authors were able to identify candidate materials responsible for taste and odour problem in drinking water.

2.3 Materials used in Drinking Water Storage and Distribution System

There is a large selection of materials commercially available for distribution and storing of water. It is essential first to determine the end-product requirements in terms of water quality needed for a particular application. The correct choice of materials for every part of conveyance, and storage, minimizing contact time during conveyance, and exclusion of airborne particles are the basis for a successful system of water transport and storage (Ross, 1991).

Common materials used in drinking water storage and distribution systems include, (Tomboulian et al. 2004);

- Pipes and mains: cast iron, ductile iron, steel, reinforced concrete, asbestos cement; thermoplastics, including polyvinyl chloride (PVC), chlorinated polyvinyl chloride (CPVC), high density polyethylene (HDPE), polybutadiene; composites such as glass fibre reinforced plastic (GRP) using thermoplastic epoxy or polyester resins
- Home plumbing: copper, lead, galvanized steel, and thermoplastics
- Tanks and reservoir: cementitious products with organic additives
- Ancillary equipment and its coating, joining, and sealing materials: gaskets, o-rings, fittings, valves, paints, primers, additives, adhesives, solder
- Lining and coatings: epoxy, polyester, polyurethane, and polyacrylate resins; cement mortar, bituminous materials
- Sealing systems: rubbers, including ethylene-propylene terpolymer (EPDM), styrene-butadiene rubber (SBR), nitrile-butadiene rubber (NBR), silicones, polybutenes.

2.3.1 Types of Pipes

The pipes are usually classified according to the materials of which these are made. Thus the various types of pipes are as follows (Modi, 2006);

- Cast iron pipes
- Wrought iron pipes
- Steel pipes
- Cement concrete pipes-Reinforced cement concrete pipes, steel cylinder reinforced concrete pipes (or Hume steel pipes) and Prestressed concrete pipes
- Asbestos cement pipes
- Galvanised iron pipes (G.I. pipes)
- Wood pipes
- Copper pipes
- Lead pipes
- Plastic pipes

2.3.1.1 Cast Iron

Cast iron pipes are extensively used for conveyance of water in a water supply scheme of a town or city. The cast iron is highly resistant to corrosion and possesses other desirable properties. Hence cast iron pipes are quite durable and have a useful life span of around 100 years or so.

Earlier cast iron pipes were manufactured only from pig iron which is also called grey iron. Now-a-days besides pig iron, ductile iron, also called nodular iron or spheroidal graphite iron, is also used extremely for manufacturing cast iron pipes. The cast iron manufactured from ductile iron are usually designated ductile iron pipes in order to distinguish them from those manufactured from pig iron which are designated as cast iron pipes. As compared to pig iron, ductile iron offers: (a) high resistance against breakage due to impact, (b) high tensile strength nearly that of steel, and (c) traditional corrosion resistance of cast iron. The cast iron pipes as well as ductile iron pipes are joined either by socket and spigot joints or by flanged joints.

2.3.1.2 Wrought Iron Pipes

Wrought iron pipes are manufactured by rolling the wrought iron plates to proper diameter and welding the edges. These pipes are made with internal diameters ranging from 3mm to 500mm. As compared with cast iron pipes, the wrought iron pipes are light in weight, can be easily cut, threaded and worked, and present a neater appearance, but are more costly, less durable (with life span up to 50 years) and more liable to corrosion. Hence these pipes are generally used for installations within buildings were this are protected against the agent of corrosion which are also sometimes galvanized (i.e. inside and outside surfaces of the pipes are coated with zinc) to protect them from rusting. The wrought iron pipes are joined together by mechanical coupling or screwed and socketed joints. However, the wrought iron pipes are not commonly used in water supply schemes.

2.3.1.3 Steel Pipes

Steel pipes are fabricated by rolling the mild steel plates to proper diameter and either welding or riveting the edges. The joints may be transverse and longitudinal and spiral. Welded pipes are smoother and stronger than riveted pipes and hence welded pipes are more commonly used. Spiral welded steel pipes are made in sizes ranging from 150mm to 900mm in diameter and in lengths up to12m.However welded steel pipes of size as large as 2400mm in diameter are also made. Since steel pipes are not cast but made by welding or riveting the steel plates, these may vary both in length and diameter.

As compared to cast iron pipes, steel pipes are stronger, can withstand high internal pressure and are light in weight. However, the main drawback of steel pipes being that these pipes cannot withstand high negative (or vacuum) pressure. Steel pipes get rusted quickly which reduces there life as well as their carrying capacities.

These pipes may also get corroded by acidic and alkaline waters. As such the inner as well as the outer surfaces of steel pipes are provided with protective coatings, the life of steel pipes may range from about 20 to 50 years. The steel pipes up to 250 internal diameters are generally galvanized to protect them from rusting. The steel pipes are also coated from inside as well as outside with cement mortar or cement concrete which are then known as steel cylinder reinforced concrete pipe or hume steel pipes. Steel pipes are mainly used on long pipe as trunk mains and these are seldom used as distribution pipes because they require more time for repairs during breakdown.

2.3.1.4 Cement Concrete Pipes

The cement concrete pipes used may be plain cement concrete pipes (or unreinforced cement concrete pipes), reinforced cement concrete pipes (R.C.C pipes), or prestressed concrete pipes. The plain cement concrete pipes are used for low heads say up to 15m, the reinforced cement concrete pipes are used for medium heads say up to 75m, and the prestressed concrete pipes are used for large heads. Concrete pipes may be cast at the site or this may be manufactured in the factories or casting yards and then transported to the site.

The ordinary reinforced cement concrete pipes are not suitable for use in situations where water pressure exceed 75m. In situations where relatively high water pressures are met with other types of cement concrete pipes viz, steel cylinder reinforced concrete pipes and prestressed concrete pipes are often used.

2.3.1.5 Asbestos Cement Pipes

The asbestos cement is manufactured from a mixture of asbestos fibres and cement combined under pressure into a dense homogenous structure in which a strong bond is effected between the cement and the asbestos fibre. These pipes are manufactured with internal diameters varying from 50mm to 900mm. The 50mm to

80mm diameter pipes are made in 1.5m to 3m lengths and the 100mm and larger diameter pipes generally made in four different grades to withstand internal bursting pressures of 0.35 N/mm^2, 0.70 N/mm^2, 1.05 N/mm^2, and 1.4 N/mm^2. These pipes are provided with plain ends and the pipes are joined by means of a special type of joint or coupling called slip type sleeve joint. The commonly used slip type sleeve joints with different trade names are Simplex joints and Ring-tite coupling.

The asbestos-cement pipes can be tapped and threaded for service connections in the same manner as iron pipes, these can be cut to any desired length, shorter than standard, and at any angle, by means of a common wood saw and mitre box. The asbestos-cement pipes are light in weight ($1/4^{th}$ that of cast iron pipes of the same size) and hence, it is easy to handle and transport. It is highly resistant to corrosion and is relatively cheap. However, they do not have much strength and are brittle. As such these pipes cannot stand impact forces during handling and transportation, and also the vibration of traffic when placed under the road.

2.3.1.6 Galvanized Iron Pipes (G.I pipes)

These are the mild steel or wrought iron pipes which are galvanised i.e. provided with protective coating of zinc on the inner and the outer surfaces of the pipes. These pipes are most commonly used for service connections and for water pipe fittings inside the houses and buildings. The diameters of these pipes vary from 6mm to 100mm, and they are available in varying lengths. For water pipe fittings mostly 12mm and 25mm diameter pipes are used which are available in length of 7m or so. However, larger diameter pipes are available in small lengths. These pipes are easy to join. For joining these pipes mostly screwed socket joints are used. The life span of these pipes is about 20 years or so. These pipes may get corroded by acidic or alkaline or otherwise activated waters. Further these pipes are also liable to incrustation.

2.3.1.7 Wood Pipes

These pipes are made from staves and planks of wood held together by steel bands. These pipes are light in weight but they cannot resist high internal water pressure. Further these pipes should be kept constantly filled with water because the alternative conditions of dryness and wetness lead to wet rot which is one of the most common causes of deterioration of these pipes. Wood is, however, the least durable of the pipe materials, and hence the wood pipes are now rarely adopted for the conveyance of water.

2.3.1.8 Copper Pipes

Copper pipes do not sag due to hot water and therefore there use is restricted for the conveyance of hot water in buildings and steam boilers. These pipes are also used in goose neck in house connections because these pipes can be bent easily. The copper pipes are highly resistant to acidic as well as alkaline waters and hence they are not liable to corrosion. However, the copper pipes very costly and hence these pipes are not used for distribution of water.

2.3.1.9 Lead Pipes

Lead pipes are usually not adopted for the conveyance of water because these pipes may cause lead poisoning. These pipes are mostly used in sanitary fittings. The lead pipes are also used for the appliances adopted for alum and chlorination dosing processes in water treatment plants. These pipes ca be easily bent and hence less number of special fittings will be required. They cannot be used to carry hot water as they sag due to heat.

2.3.1.10 Plastic Pipes

Plastics are, in general, synthetic resins of high molecular weight, polymerized from simple compounds by heat, pressure and catalysis. The plastic is a relatively new material and its use has come in a big way in almost all the fields of engineering. The use of plastic pipes for the conveyance of water has increased due to various types of plastic pipes being manufactured. The three common types of plastic are;

i. the low density polyethylene pipes (LDPE pipes),

ii. the high density polyethylene pipes (HDPE pipes)

iii. Unplasticized polyvinyl chloride pipes (PVC).

These pipes have the inherent characteristics of higher strength to weight ratio, greater environmental stability and flexibility and better resistance to corrosion and bacterial contamination. These pipes are available in sizes up to about 500mm internal diameter and can withstand internal water pressure up to 1 N/mm^2 (or 100m head). The life span of these pipes is about 50 years or so. Because of there excellent merits these pipes especially the unplasticized PVC and HDPE pipes are becoming increasingly popular for use in the distribution systems of water supply schemes for conveyance of water on long runs for point to point distribution. Moreover, these pipes also offer effective alternatives to conventional galvanized iron pipes (G.I pipes) for use as water pipe fittings in buildings. However these pipes possess low resistance to heat, with rise in temperature the tensile strength of the plastic pipes decreases rapidly. It may be difficult to obtain plastic pipes of uniform quality. Sometimes, some types of plastics may impart undesirable taste and odour, and also toxicity to water.

2.4.0 Appurtenances in Distribution System

In order to make distribution of water easy and effective, various appurtenances are required to be used in a distribution system. Some of the appurtenances which are commonly used in a distribution system are as follows (Modi, 2006);

1. Valves
2. Manholes
3. Fire hydrants
4. Water meters.

2.4.1 Valves

Valves are provided in the pipeline to control the flow of water, to isolate and drain pipeline selections for test, inspection, cleaning and repairs, to regulate pressures and to release or admit air. The various valves commonly used in a distribution system are as follows;

(a) Sluice valves or Gate valves

(b) Butterfly valves

(c) Globe valves

(d) Check valves

(e) Air valves or Air-relief valves

(f) Pressure-relief valves

(g) Scour valves or Blow-off valves or Drain valves.

2.4.2 Manholes

Manholes are provided at suitable intervals along the pipeline. They are helpful during construction and later on serve for inspection and repairs. These are usually spaced 300 to 600m apart on large pipelines. Their most useful positions are at summits and downstream of main valves. They are commonly provided in the case of steel and concrete pipelines and are less common in the case of cast iron and asbestos cement pipelines.

2.4.3 Fire Hydrants

A fire hydrant is an outlet provided in a pipeline for tapping water mainly for the purpose of fire fighting (or fire extinguishing). However, sometimes these may also be used for withdrawing water for certain other purposes such as sprinkling on roads, flushing streets, e t c.

2.4.4 Water Meters

Water meters are the devices which are installed in pipelines to measure the quantity of water flowing through them. The water flowing through pipelines is supplied to various consumers for domestic, industrial and commercial uses and its measurement is necessary to charge the consumers according to the quantity of water supplied to them.

The water meters may be classified into the following two categories.

i. Inferential type meters or velocity meters

ii. Displacement type meters.

2.5 Service Reservoirs

Reservoirs are used in a distribution system to provide storage to meet fluctuations in demand of water, to provide storage for fire fighting and emergencies such as breakdowns, repairs, etc, and to stabilize pressure in the distribution system. These reservoirs may be constructed of brick masonry, stone masonry, cement concrete-plain, reinforced or prestressed and steel. These reservoirs are always covered to avoid contamination and prevent algal growths (Modi, 2006).

Finished water reservoirs may be located near the beginning of a distribution system, but most often they are situated in suburban areas. Local topography plays an important part in determining the use of low-level or high-level reservoirs. Ground reservoirs are constructed by earth embankment. Such reservoirs are lined with concrete, Gunite, asphalt, or a plastic sheet over the sides and bottom to prevent or reduce water loss in storage, (GeldReich, 1990).

2.6 Requirement of a good Distribution System

A good distribution system should satisfy the following requirement, (Modi, 2006):

i. It should be capable of supplying water to all the consumers at adequate residual pressure in sufficient quantity.

ii. It should be capable of meeting the fire demand simultaneously.

iii. The distribution system should be completely watertight and it should maintain the degree of purity.

iv. It should be easy to operate and maintain.

v. The initial cost of the distribution system should be as low as possible.

vi. The distribution system should be thoroughly reliable. This would involved (a) interconnecting all the water mains, and controlling flow through sluice valves located at suitable points, so as to ensure an uninterrupted supply of water to all other sections when one of the sections has to be cut out of service following breakdown and consequent repair, (b) laying the mains with a sufficient cover of about 0.9m under roads and streets, so that they are not open to any damage because of any hazard of passing traffic.

2.7 Distribution of Water

With respect to the topography, the location of the source, and other considerations, water can be transported to a community in a number of ways for transportation of water, canals, flumes, tunnels and pressure pipes can be employed. Depending upon the method of distribution, water distribution systems may be classified as follows: gravity system, combined gravity and pumping system, and pumping system (Modi, 2006).

2.7.1 Gravity System

In this system water is conveyed through pipes by gravity only. This system is adopted where the treated water to be supplied is available at a higher level than that of distribution areas. The gravity system is the most reliable system of distribution. However, in case of a fire, pumps may be used to develop high pressures for fire fighting purpose.

2.7.2 Combined Gravity and Pumping System

In this system, the treated water to be supplied is pumped and stored in an elevated distribution reservoir from which it is supplied to the consumers under gravity. This system is adopted where the treated water to be supplied is available at almost the same level as the area of distribution, and hence in order to obtain sufficient distribution pressure the water is pumped to a reservoir located on higher ground or elevated on a tower. From the elevated reservoir the water is then conveyed through pipes under gravity.

2.7.3 Pumping System

In this system, water is pumped directly into the distribution mains. The number of pumps required in this system will depend on the demand of water.

Moreover, the pumps may have to be worked at various rates depending on the demand of water.

2.8 Water Characteristics

Water which is absolutely pure is not found in nature; even water vapour condensing in the air contains solids, dissolved salts, and dissolved gasses (McGhee 1991). It is therefore essential to assertion the character and/or quality of water available from different sources. This would involve the determination of the various impurities which may be present in the water available from the various sources.

Water characteristics may be classified into the following three categories.

i. Physical characteristics

ii. Chemical characteristics

iii. Bacteriological characteristics.

2.8.1 Physical Characteristics

The physical characteristics of water are;

i. Colour: Colour may be imparted to water by the presence of natural metallic ions, peat, humus etc. An undesirable appearance is produced by colour in water and people may not like to drink coloured water. Most consumer object to colour.

ii. Taste and Odour: The taste of water may be bitter, Salty, sour, and sweet. Similarly water may possess odour such as unpleasant, earthy, fishy, grassy, mouldy, peaty and sweetish. Taste and odour are closely related and this may be imparted to water by the presence of dissolved gases such as H_2S, CH_4, CO_2, O_2 etc., combined with organic matter, minerals substances like NaCl, iron compounds, carbonates and sulphates of other elements, and phenol and other terry or oily matter. Water to be supplied from a public water supply scheme should not have any undesirable or objectionable taste and odour.

iii. Turbidity: Water becomes turbid when substances like silt, clay, finely divided organic and inorganic matter gives the water a cloudy appearance. Turbid water is aesthetically unattractive.]

iv. Temperature: This is simply the degree of hotness or coldness of the water sample. The temperature of treated water varies depending on the time it took along the pipe network to its destination; also it depends on the temperature of the surrounding of the pipes. It is measured by the use of thermometer and a conductivity/TDs meter.

v. Conductivity: Conductivity is the measure of the ability of a solution such as water to carry electric current as this ability is dependent upon the presence of ions in solution; a conductivity measurement is an excellent indicator of the total dissolved solid in water. Units are in Millisiemen per centimetre (ms/cm). For most water a factor in the range 0.5-0.70 multiplied by the conductivity gives a close approximation of the dissolved solid in mg/l, factor less than 0.50 for water contains a lot of free acid, and higher than 0.70 for highly saline water.

vi. Total solids: Total dissolved solids is a quantitative measurement of the dissolved silt in water. For given water the dissolved solids, concentration can be course directly related to the conductivity. The dissolved solids make up the mineral constituents of water. These include all the anions and cat ions of any dissolved silica present, the removal is usually expressed in mg/l.

2.8.2 Chemical Characteristics of Water

The chemical characteristics of water are quantified in terms of the inorganic and organic constituent that is present in the water sample; it is used to access the suitability of use as public water supply. The inorganic constituents found in water supply are from either the natural sources, the mingling of contaminated water and waste water or the dissolution of materials used for the storage and transportation of water, while the P^H is the measure of the acidic or basic nature of the water sample and it is defined as the logarithm of the reciprocal of the hydrogen ion concentration in moles per litre. The presences of compound affect the P^H of water e.g. the presence of carbon dioxide

Dissolved metallic ions, such as calcium, magnesium, iron, aluminium, zinc, and manganese contribute to total hardness of water supplied for human use.

2.8.3 Bacteriological Characteristics

These are the properties relating to the effect of living organisms on water. That is, the bacterium which is found in water samples; the presence of bacteria, algae, fungi and protozoa in water supply may be as a result of leakages along distribution networks or irregular cleaning of the various unit in the treatment plant. Any indication of the presence of such can be viewed with a powerful microscope. The disease causing bacterial are called pathogenic bacteria, where the non-pathogenic bacteria are harmless.

Escherichia coli (colon bacilli) are a bacterium that inhabits the intestine of warm blooded animals. They are usually harmless bacteria exerted with faeces and there presence in water indicates the presence of pathogenic bacteria.

2.9 Water Quality Standard

The impart of contaminated drinking-water on health has been well documented and range from massive outbreaks of infectious and parasitic diseases to subtle chronic toxicological effects. Good-quality water for household purposes must be free of harmful bacterial, sediment, objectionable minerals, taste and odour etc.; however it has been found that the presence of certain minerals such as iron, calcium, and magnesium in small quantities in the water may be useful to human body (Modi, 2006).

Accordingly, most standards recommend an acceptable quantity of materials to make a water sample quantity useful for human use. International and national organizations have from time to time prepared guidelines and regulations for the quality of water used for specific applications. The first drinking water quality standards were issued at least 4000 years ago (Cotruvo and Vogt, 1990). Since then, the water quality standards have undergone continuous modification. It is to be expected that, with new analytical techniques and more information concerning the health effects of water contaminations, the standards will continue to change.

World Health Organization (WHO), National Agency for Food and Drug Administration and Control (NAFDAC. Nigeria), and National Primary Drinking Water Regulations (NPDWR. US) (2001) recommend an acceptable quantity of materials to make a water sample quantity useful for human use.

2.10 Sampling

The objective of sampling is to collect a portion of material small enough in volume to be transported conveniently and handled in the laboratory while still accurately representing the material being sampled. This implies that the relative proportion or concentrations of all pertinent components will be the same in the samples as in the materials being sampled, and that the samples will be handled in such away that no significant changes in composition occur before the tests are made.

A variety of equipment has been devised for collection of water samples. The type of apparatus used will to a certain extent be determined by the sampling location and the information being sought for. In general, the collecting apparatus should meet the following requirements;

- It should be capable of being sterilized; this is most importantly essential for bacteriological analysis.
- It should be capable of collecting a sufficient volume of water for analysis.
- It should be strong and robust enough to withstand any form of rough handling which it may be subjected to.
- It should be constructed with such materials that are considered inert.

CHAPTER THREE

3.0 MATERIALS AND METHOD

3.1 Background

The effect of distribution system materials on water quality were evaluated by direct field observation and also, by collecting and analysing water samples taken from specific points in the distribution system of the Chanchaga waterworks in Minna, Niger state. The test materials were exposed in drinking water pipelines, reservoirs or tanks with intermittent water exchange.

3.2 Study Area

Location**:** The study area which includes, Chanchaga treatment plant situated in Chanchaga, some representative points in the distribution network reservoirs which is spread all over the state capital Minna, is located within longitude 6^0 30^0E, to longitude 5^0 30^0E.

Climate and vegetation: The total annual rainfall spreads over the month of April to October with highest month being in August, the sum annual rainfall is between 1038.3 – 1423.4mm and the mean annual temperature ranges between 32^0 and 29^0 during the dry season.

Relief: The relief of the study area is similar to the topography of most of the Northern parts of Nigeria. It is not predominantly undulating relief; rather it is mostly flat lying land with some sparsely distributed hills. Some of such hills are used for the location of the storage tanks/reservoirs for water distribution to areas of lower plains.

3.3 History of Chanchaga Waterworks

Chanchaga waterworks came into being in 1963 with the erection of what is today known as Paiko treatment plant to serve Minna and its environs being a small community. With increase in population of inhabitants living in the area, there was need for more water that is portable. This lead to the construction of a new plant named Biwater treatment plant in 1976; the same plant was extended by Constane, a construction company, in 1982. Due to population explosion (appendix ii), water demand rose drastically, this lead to the construction of another plant named Impresit treatment plant, bringing to three the number of treatment plants in Chanchaga waterworks.

Paiko plant was so named based on the area it supplies presently which is Paiko and its environs, Biwater and Impresit plants named after the engineering companies that erected them; both supply Minna town of which Chanchaga is inclusive, although always regarded as an outskirt of the town.

Presently, the total production capacity for the three plants is 71million litre per day (if the plants functions effectively) which is not up to water demand of the town placed roughly at about 150million litre per day.

3.3.1 Distribution Network System and Storage Tank Capacity of the Chanchaga Waterworks

Due to the location of the treatment plant, topography of the town, and other considerations, the Chanchaga waterworks combines the gravity and pumping system for water distribution. From the main treatment plant in Chanchaga which comprises of the old and new treatment plants, the treated water is collectively pumped to various storage tanks in the city, located on higher ground. From the elevated reservoir the water is then conveyed through pipes under gravity.

3.3.1.1 Biwater Tank

Location: It is located almost opposite Water Corporation's head office in Minna by western-bye pass, (plate 3.1).

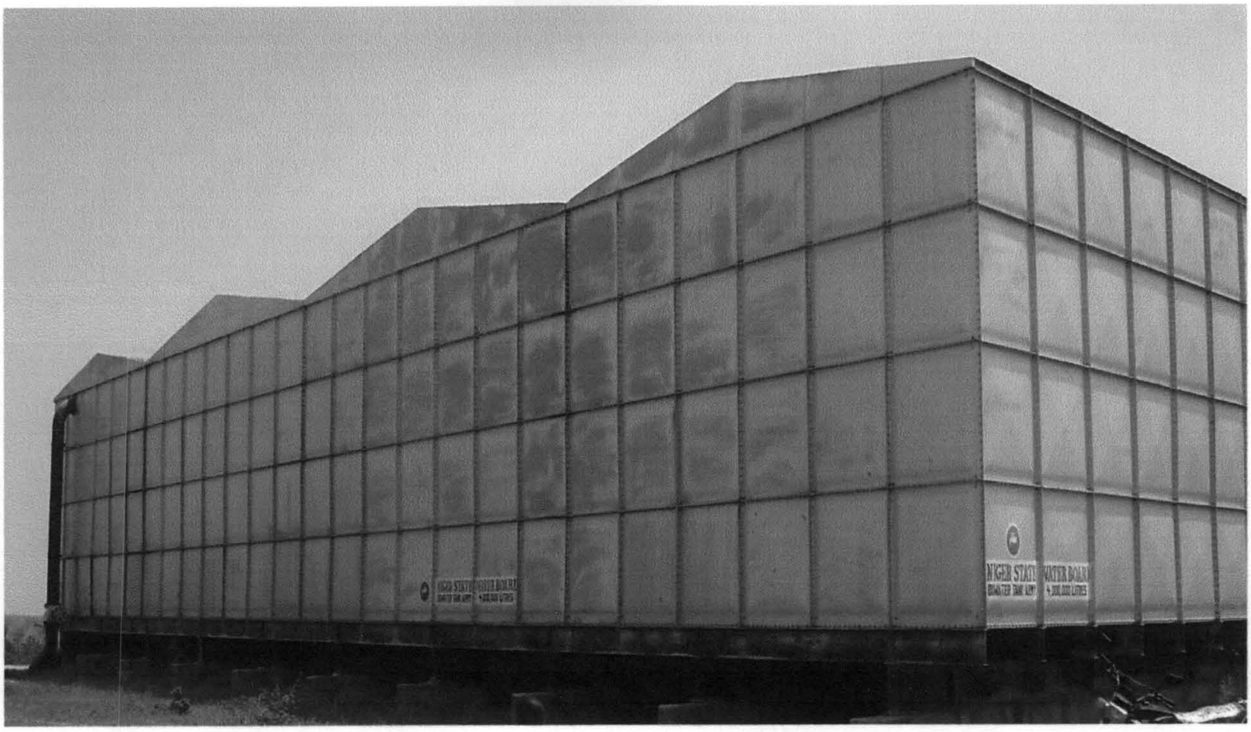

Plate 3.1: Biwater Reservoir/Tank

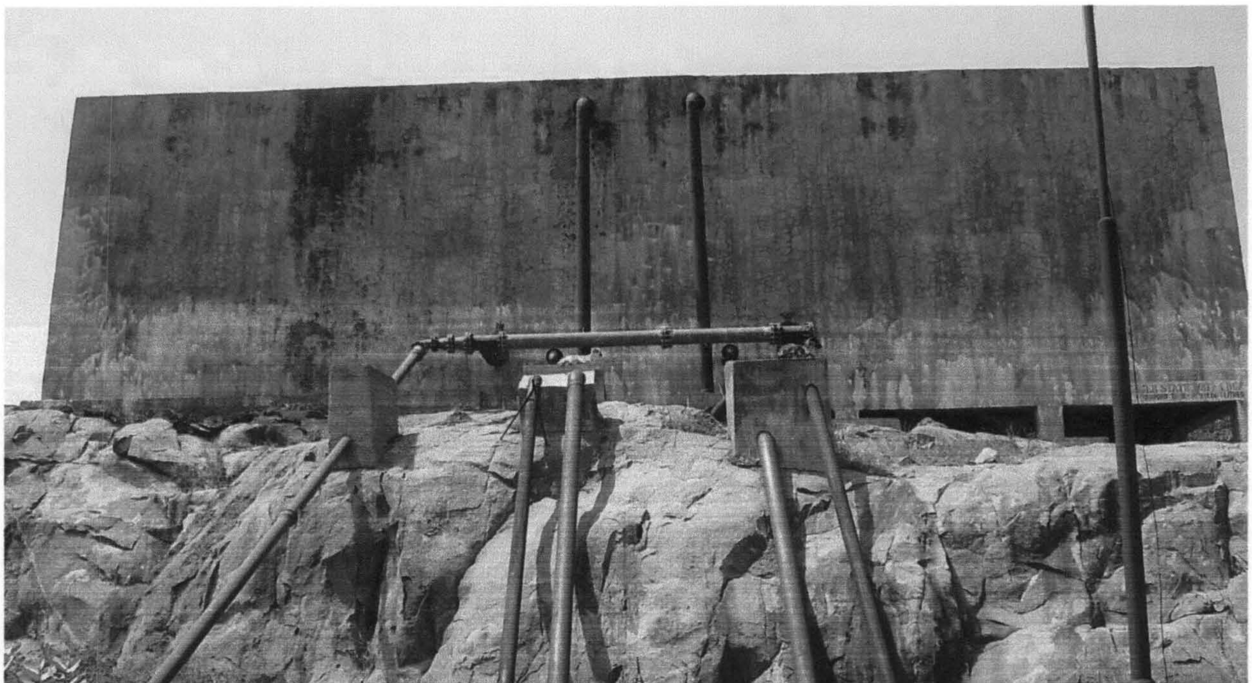

Plate 3.2: Shiroro Reservoir/Tank. Reservoirs are located on higher ground to distribute water by gravity.

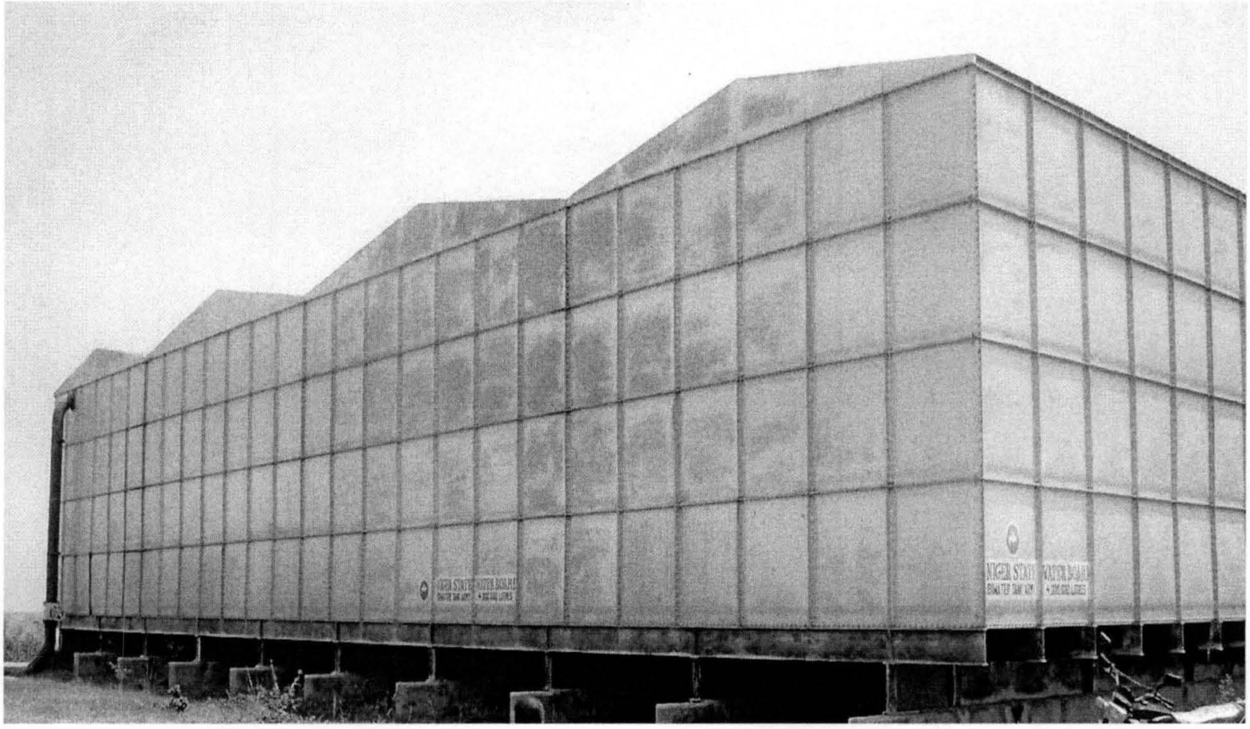

Plate 3.1: Biwater Reservoir/Tank

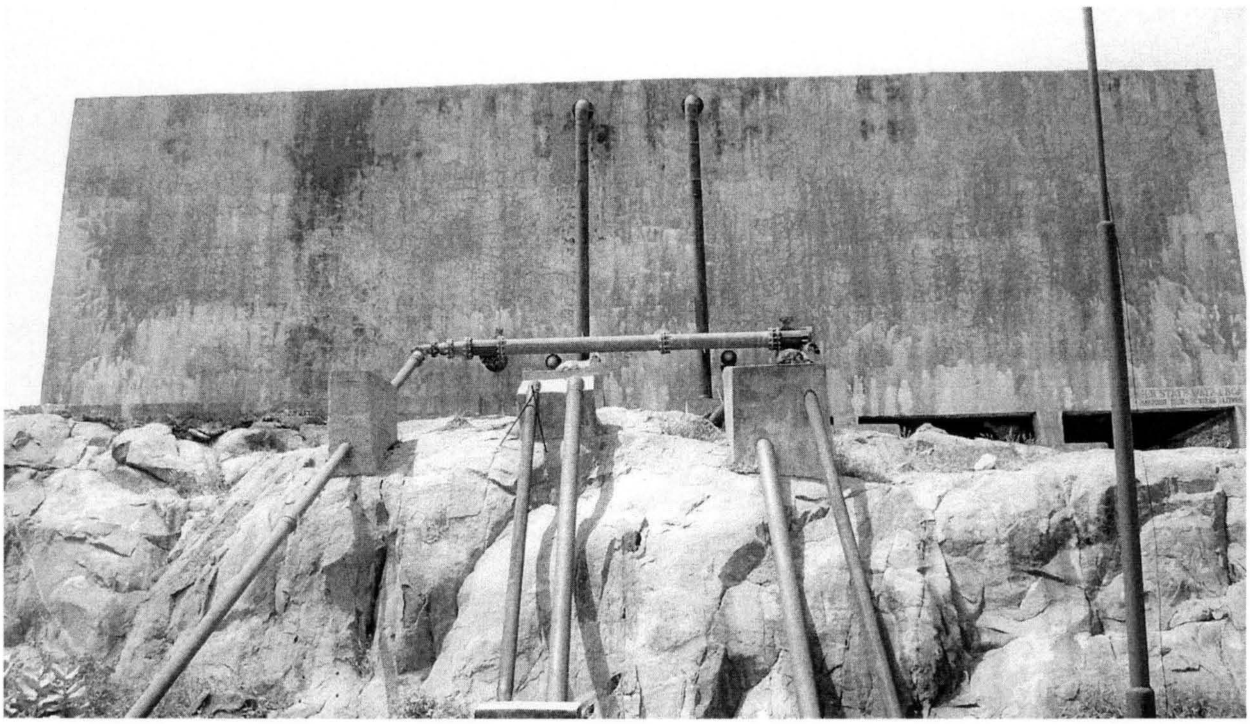

Plate 3.2: Shiroro Reservoir/Tank. Reservoirs are located on higher ground to distribute water by gravity.

Capacity: 10 million litres, and serves as both balance tank and reservoir. Supply areas: supplies army barracks and shango environs.

3.3.1.2 Shiroro Tank

Location: Situated near Shiroro hotel on top of a hill, (plate 3.2).

Capacity: 2 million litres, serves as balance tank and reservoir.

Supply Areas: Shiroro hotel, Sauka Kayuta, and Barkin Sale areas.

3.3.1.3 Top Medical Tank

Location: Located high above the top medical road after the hill.

Capacity: 2 million litres and serves as both balance tank and reservoir.

Supply Areas: Tunga east mainly.

3.3.1.4 INEC Tank

Location: Situated as the name implies, by INEC office.

Capacity: 1 million litres and serves both as a balance tank and reservoir.

Supply Areas: Tunga environs and police barracks.

3.3.1.5 Uphill Tank

Location: Situated close to IBB house on the hill. It is circular in shape.

Capacity: 7 million litres and serves as both balance tank and a reservoir.

Supply Areas: Mobil area and Maitunbi.

3.3.1.6 Paida Tank

Location: Situated in Paida area of Niger state.

Capacity: 4 million litres and serves both as balance tank and a reservoir.

Supply Areas: Supplies few areas in Bosso and F. layout.

3.3.1.7 Dutsen Kura Tank

Location: Situated around Dutsen Kura Gwari.

Capacity: 10 million litres and serves both as a balance tank and a reservoir.

Supply Areas: Supply Dutsen Kura areas and Bosso estate.

3.4 Sampling

3.4.1 Sampling Site

Visits were made to Chanchaga waterworks and to distribution networks to select sampling sites. The sampling sites selected are;

I. Chanchaga treatment plant outlet

II. Biwater tank (Steel tank)

III. Shiroro tank (concrete tank)

3.4.2 Sampling Procedure and Collection

Sampling bottles were carefully cleaned/rinsed and sterilized. From the treatment outlet, a point for collection of water was selected, which is a good representation of finished water leaving the treatment works. Also, for the samples collected from the distribution network reservoir, a tap that is supplying water from service pipe directly connected with the reservoirs' main was selected. The tap was opened fully and allowed to run to waste for 2 – 3 minutes, to permit the clearing of the service line. The reservoirs received a good flow of water, as it was situated nearest the distribution system.

The sampling bottles was filled until it was almost full, each samples collected was numbered (labelled) with date and time. Finally, the samples were dispatched at once to the laboratory for analysis.

3.5 Laboratory Analysis

3.5.1 Materials for Laboratory Analysis

The equipments and materials used for this analysis ranges from complex computerized equipment to simple ones like the water containers. Cross sections of the equipments include;

- Atomic absorption Spectrophotometer

- Incubator
- Autoclaves
- Bunsen burner
- Inoculating loop
- p^H meter
- Petri dishes
- Pipettes
- Reagent and chemicals
- Refrigerator
- Oven
- Desiccators
- Water containers.

3.6 Analysis of Physical Characteristics

In the process of carrying out the physical analysis of all the water samples collected, the major parameters considered were taste and odour, colour, and turbidity.

3.6.1 Taste and Odour

Odour and taste of any water depends on the actual contact of the simulating substance with the appropriate human organs. The taste is by the tongue, while odour is by the nose. Although it is limited in application as contaminated water may be dangerous for taste testing. No odour was perceived in all the samples collected. Also the water was tasteless.

3.6.2 Colour

Monitoring colour in drinking water may be through observation or by colour measurement using a box or a spectrophotometer. The colour of all samples collected was observed, and the result recorded.

3.6.3 Turbidity

This was determined using a turbidimeter (Nephelometer). The measurement of turbidity of water by this meter is based on a comparison of the intensity of light scattered by the water sample under defined condition with the intensity of light scattered by a standard reference suspension under the same conditions. The intensity of light scattered at right angles to the incident light using formazin polymer as the reference standard suspension was measured and computed as the turbidity.

3.7 Analysis of Chemical Characteristics

In the chemical analysis of all the water samples collected, test where carried out to determine the Total solids present in the water samples and its P^H, Sulphate, Chlorine, Nitrate, Copper, Lead, Manganese, and Iron.

3.7.1 Total Solid

This was determined by collecting a measured volume (10ml) of the water sample and placing it in a crucible, then allowing it to evaporate to dryness in an oven at 105^0C. The weight of the dry residue left is measured and computed as the Total Solids (TS) in mg/l.

The procedure was repeated for all samples and results recorded.

3.7.2 p^H

In the laboratory the p^H of the water was measured using a p^H meter, the result obtained for all the samples was recorded.

3.7.3 Chloride

The chloride content was measured in the laboratory by titrating the water with standard (N/35.5) silver nitrate ($AgNO_3$) solution using potassium chromate ($K_2C_rO_7$) as indicator. The result obtained using the same procedure for all the samples, was record.

3.7.4 Sulphate

This was determined by taking a measured volume (20ml) of water sample and adding 1 drop of phenolphthalein. 0.1 amount of NaOH was further added to make the water sample just neutral. Also 0.15g of tetrahydroxy quinine (THQ) indicator was put in it and stirred to dissolve completely. With the addition of 95% alcohol, which is about half the volume of the water sample, it was titrated with 0,01 amount of barium chloride solution until the stable colour of the solution matches with the standard glass colour filter. The reading of the burette was taken and computed as the amount of sulphate in mg/l.

These procedures were repeated for all the samples and the result recorded.

3.7.5 Chlorine (free)

Method for free chlorine analysis

The machine used was the DR/2000 Direct reading spectrophotometer (DPD method)

Procedure for free chlorine analysis

- The stored program number for free chlorine (Cl_2) was entered
- The wavelength was rotated until the small display showed 530nm
- RAED/ENTER key was pressed and the display showed mg/l Cl_2

- A sample cell with 25ml of sample (the blank was filled with deionised water and placed into the cell holder)
- The ZERO key was pressed and the display showed: WAIT then ; 0.00 mg/l Cl_2
- Another cell with 25ml of the water sample was filled
- The contents of one DPD free Cl_2 powder pillow was added to the sample cell (the prepared sample)
- The sample was stoppered and shaken for 20 seconds and then the stopper was removed
- Within a minute of the reagent been added, the prepared sample was placed into the cell holder and the light shield was closed
- The READ/ENTER key was pressed and the display showed: WAIT then the result was displayed in mg/l Cl_2
- The same procedure was repeated for all samples and the results recorded.

3.7.6 Nitrate

Same DR/2000 Direct reading spectrophotometer was used to analyse nitrate and the method employed was cadmium production.

Procedure for Nitrate analysis

- The stored program for Nitrate was entered and the wavelength dial was rotated until the small display showed 507 nm
- The READ/ENTER key was pressed and the display showed mg/l NNO_3L
- A 50ml graduated mixing cylinder was filled to the 30ml mark with the sample
- A contents of Nitra Ver 6 Nitrate reagent powder pillow was added to the cylinder and stoppered

- SHIFT TIMER WAS pressed. A 3 minute reaction period started while the cylinder was shaken continuously during the 3 minute period
- A 2 minute period was also allowed for the cadmium to settle
- 25ml of the sample was poured into a sample cell
- A content of Nitri Ver 3 Nitrite reagent powder pillow was added to sample cell (the prepared sample) was stoppered and shaken to dissolve
- SHIFT TIMER was pressed, and after a 10 minute reaction the display showed mg/l NNO_3L
- Another sample cell (the blank) was filled with 25ml of sample
- The blank was placed into the cell holder and the light shred closed
- The ZERO key was pressed another display showed 0. Units mg/l NNO_3L
- The prepared sample cell was inserted into the cell holder and the light shield closed
- The READ/ENTER key was pressed and the display showed: WAIT and the result was displayed in mg/l NNO_3L
- The procedure was repeated for all the samples and result recorded.

3.7.7 Copper, Lead, Manganese, and Iron

Water samples was filtered and presented for instrumentational analysis of the element of interest (Cu, Pb, Mn and Fe) using the bulk Atomic Absorption Spectrophotometer (AAS). The AAS was firstly calibrated using standard solutions of the elements of interest and the sample readings obtained and expressed in mg/l.

The procedure was repeated for all the samples and the result recorded.

3.8 Analysis of Bacteriological Characteristics

In the analysis of bacteriological characteristics of samples, the total count or agar plate count test method were carried out. This method detects the presence of bacterial of coli form group.

In this test, bacterial were cultivated on specially prepared medium of agar for different solutions of sample of water with distilled water. The dilution used was 1ml of the water sample. The diluted samples were placed in an incubator for 24 hours at 37^0C. The bacterial colonies formed, are then counted and the results computed per 100ml. In all the water samples tested, the results show no bacterial growth.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Background

During the course of this project research, investigations and experiments were carried out at different areas concerning the project in order to achieve the aims and objectives of the project. This chapter is therefore designed for the presentation and discussion of results.

4.2 Presentation of Results

The study result which where obtained from various experiment and investigation are presented as follows.

4.2.1 Nature of Material used for Water Distribution

As stated in the literature review, there are large selections of materials commercially available for distribution and for storage of water. The nature of materials used by the water utility for water distribution and storage are illustrated in Table 4.1 below. The selection of appropriate material is important to ensure that water is distributed safely. This requires a systematic approach based on reliable test methods and criteria.

TABLE 4.1 Nature of materials used by the water utility for the storage and distribution of water

Test material	Materials of construction	Internal lining materials
Rising mains	Ductile Iron	Cement Mortar
Tanks and Reservoir		
a. Biwater Tank/Reservoir	Steel	Bituminous material
b. Shiroro tank/reservoir	Reinforced Concrete	Concrete Mortar

4.2.2 Water Quality Evaluation

The water quality results obtained from the sample analysis is illustrated in Table 4.2. While the maximum acceptable concentration (WHO 2001) and maximum allowable concentration (NAFDAC, Nigeria 2001) is also illustrated in the same table (i.e. Table 4.2).

4.3. Discussion of Results

The study discussion is based on the findings of the research works. Result of the nature of distribution system materials and the water quality evaluation, hence, the effect of distribution system materials on drinking water quality will be discussed.

TABLE 4.2 Results of water quality analysis, guidelines on drinking water by world health organization (WHO), and national agency for food and drug administration and control (NAFDAC, Nigeria).

S/No	TEST	SAMPLES A^{Ψ}	B^{*}	$C^{€}$	Max. Acceptable Conc. (WHO)	Max. Allowable Conc. (NAFDAC)
1.	Colour	Extremely pure	Moderately pure	Pure	5 TCU	-
2.	Taste and Odor	unobjectionable	unobjectionable	unobjectionable	unobjectionable	unobjectionable
3.	Chlorine(free)	0.35mg/l	0.45mg/l	0.56mg/l	0.30mg/l	
4.	P^H Range	5.9	5.9	6.1	7.0 – 8.5	6.5 – 8.5
5.	Turbidity	5 NTU	7 NTU	4 NTU	5 NTU	5 NTU
6.	Total Solids	403.7 mg/l	457.3 mg/l	435.7 mg/l	1000 mg/l	500 mg/l
7.	Iron (Fe)	0.42 mg/l	0.46 mg/l	0.61 mg/l	0.05 – 0.3 mg/l	-
8.	Sulphate (SO_4)	260 mg/l	260 mg/l	256 mg/l	200 mg/l	200 mg/l
9.	Magnesium(Mg)	30 mg/l	30 mg/l	30 mg/l	50 mg/l	30 mg/l
10.	Chloride (Cl)	255 mg/l	300 mg/l	256 mg/l	200 mg/l	200 mg/l
11.	Copper (Cu)	0.3 mg/l	0.3 mg/l	0.3 mg/l	2.0 mg/l	-
12.	Manganese (Mn)	0.1 mg/l	0.9 mg/l	0.1 mg/l	0.5 mg/l	-
13.	Nitrate as NO_3	45 mg/l	50 mg/l	45 mg/l	50 mg/l	-
14.	Lead (Pb)	0.07 mg/l	0.09 mg/l	0.06 mg/l	0.01 mg/l	0.01 mg/l
15.	Coliform Count/ml	Not detectable in 100ml of sample tested	Not detectable in 100ml of sample tested	Not detectable in 100ml of sample tested	Must not be detectable in any 100ml per sample.	1 (Max)
16.	E. Coli Enumeration/ml	Not detectable in 100ml of sample tested	Not detectable in 100ml of sample tested	Not detectable in 100ml of sample tested	Must not be detectable in any 100ml per sample.	0 (Max)

Source: NAFDAC consumer safety bulletin (2001)

Ψ Control (sample collected from water leaving the treatment works)

* Water sample from bitumen lined reservoir (Biwater tank/reservoir)

€ Water sample from cement mortar lined reservoir (Shiroro tank/reservoir)

4.3.1 Nature of Distribution System Materials

The nature of the distribution System material used in the distribution of water will be discussed with reference to two aspects;

1. Coating and lining materials

2. Sealants for expansion joints

These are materials which come into contact directly with the water in the distribution systems.

4.3.1.1 Coating and Lining Materials

Coating and lining materials are used primarily to protect the inside of the pipe and tanks against corrosion, while also protecting the stored content from contamination. Many types of coating and lining materials are available; however only two will be discussed.

(a) Bitumen

This is among the oldest and most reliable coatings. Extremely low permeability: protect surfaces by mechanical exclusion of moisture and air, extremely water resistant; good resistant to weak mineral acids, alkalis, salts, brime solutions, and other aggressive chemicals.

(a) Bitumen is a distillation product of petroleum or coal-tar and consists of a mixture of hydrocarbon compounds, including those of (a) aromatic, C_nH_n (b) cycloaliphatic, C_nH_{2n} and (c) aliphatic nature, C_nH_{2n+2}.

The molecular weight lies between 300 and 3000. At room temperature, bitumen varies in consistency from firm to brittle. In the drinking water field it is used for lining throughout service reservoirs, pipelines and moulded parts.

Bitumen can be applied either as a solvent-free material at a temperature of $180^0 - 200^0$ or as a spreadable mix containing low boiling-point hydrocarbons as a solvent. While the solvent-free material solidifies on cooling, the solvent containing product solidifies by release of solvent over a long period of time. The solvent used is a petrol ether fraction that is a mixture of saturated hydrocarbons with a boiling point between 150^0 and 180^0.

For the investigations, a 10 million liter steel tank (plate 1) used by the water utility as a balance tank and reservoir was examined. The reservoir floor and wall surface was lined with bitumen. There was no enough information from the management of the water (works) utility to ascertain if the bitumen used was a solvent containing or solvent-free material. However from laboratory analysis and studies, it can be inferred that solvent containing bitumen was used. It may not be concluded, however that considering the number of years of service, that no more solvent is released, but only that the rate of solvent release per unit of time is no longer sufficient to give rise to considerable adverse effects on drinking water quality. The reservoir was constructed 20 – 30 years ago, and it was repeatedly drained, clean and disinfected (according to information from the management), time of last cleaning/washing was given as 5 – 10 years ago (appendix iii).

Exhaustive list of chemical found to leach out of system components is presented in appendix 1.

(b) Cement mortar

Plastic emulsions or dispersions are added to cement mortar and concrete mixes as bonding and priming agents. By this means, the mortar is rendered more plastic and more liable to adhere when used for patching or as a spray-on coat on a smooth background. In addition, the concrete acquires an enhanced binding strength, toughness and resistance towards rolling and sliding frictional loads. At the same time the density is increased and with it the resistance towards oil, petrol and de-icing salt. The following additives may be added to concrete to confer improved properties;

- Setting and hardening accelerators
- Additives for packing and mould injectors
- Additives to give a porous structure
- Additives to assist release of air
- Mineral additives
- Gas forming additives
- Swelling agents
- Additives for barriers against moisture penetration and reduction of permeability
- Bonding agents
- Chemical additives for reduction of sensitivity to alkalis
- Corrosion retarding additives
- Fungicidal, bactericidal and insecticidal additives
- Coloring materials.

It should be noted that the plastics contain not only the polymer solution, but also other additives and ancillary materials. Of the materials investigated, a cement mortar material with plastic or other organic inclusions were used to line a 2 million liters concrete reservoir (plate 2). The amounts of organic constituents released by these materials may, however, vary considerably. Bacterial multiplication takes the form of attached surface growth. These bacterial multiplications are attributable, to the cause – the release of organic constituents (from systems materials) capable of being utilized by micro-organisms. No detailed information is at present available concerning the nature of the substances added to the cement mortar.

4.3.1.2 Sealants for Expansion Joints

Sealants for expansion joints comprise epoxy resin, polysulphides and silicones.

i. Epoxy resins

Epoxy or polyepoxide is a thermosetting epoxide polymer that cures (polymerizes and crosslink's) when mixed with a catalyzing agent or "hardener". Most common epoxy resins are produced from a reaction between epichlorohydrin and bisphenol-A, (Karl 2007). Epoxy resins have achieved considerable importance in the area of protective surface treatment by reason of their excellent physical properties such as pronounced adhesion, hardness, abrasion resistance and resistance to chemical attach. Also, epoxy resins are used for sealing of expansion joints.

ii. Polysulphides

Compounds designated as organic polysulphides include compounds with several sulphides groups and also those which contain linkages in the polymer chain. The polymeric sulphides are either high melting crystalline product, e.g. polyphenylene sulphide, or in the case of purely aliphatic substitution, elastic rubber-like products, otherwise called polysulphide elastomers. The elasticity of the polysulphides is largely dependent on the alkyl residue, the sulphur content and the molecular weight.

Polysulphides have good resistance to solvents, ageing and temperature changes and are used as lining for reservoirs and as sealants for expansion joints. The organic substances likely to impair the quality of water or susceptible to microbial attach could not be determined. However, it is probable that a breakdown of the polymer skeleton was involved on account of the sulphur linkages.

iii. Silicones

Silicones constitute the largest group of sealant compositions. The simplest type of linearly polymerized silicon has the formula

$$(R_2Si -O-)_n$$

The preparation of silicones takes place via a process of directed polymerization starting from diorganyl dihalogen silanes

$$R_2SiX_2 + 2H_2O \longrightarrow R_2Si(OH)_2 + 2HX$$

$$_n(R_2Si(OH)_2) \longrightarrow (R_2SiO)_n + _n(H_2O) \qquad X = \text{Halogen}$$

These compounds contain diorganyl siloxane as the basic polymer, but with these materials only a linear polymerization is possible. For three dimensional cross-linking other substances must be used in addition, e.g. tri-functional organo-silicone compounds.

The single-component silicone rubbers employed for potable water applications polymerize slowly at room temperature under the influence of atmospheric moisture whereby chain formation occurs by condensation of SiOH-groups with the formation of the Si-O-Si bonds. By the hydrolysis of the SiX-groups, it is possible to distinguish acid, neutral and alkaline curing silicones. They produce as reaction products accompanying polymerization acetic acid, amines and oximes. These protruding groups are present both at the internal linkages and also at the terminal SiX-groups. Besides, cross linking′ agents, dryers, catalysts, and bonding agents may be incorporated. Mainly these are organometallic compounds of the element tin and titanium.

For this investigation, a ductile iron pipe, lined internally with cement mortar (the composition of the cement mortar has already been discussed under the section dealing with coating and lining materials) was investigated, cold-curing single-component silicon rubbers was used by the management of the water utility for packing of expansion joint. The basic substance is, as far as known, not microbially degraded. The silicone rubbers may however contain – as a result of their preparation and processing a number of cross linking agents, catalyst and dryers. The components which may modify the quality of water are probably the cross – linking agents, catalyst, and bonding agents, which all have easily hydrolyzed ester groups in their molecules.

4.3.2.0 Effect of Distribution System Materials on Drinking Water Quality

This is the main aim of the project. The effect of distribution system materials on drinking water quality can be determined by comparing the laboratory test results of water sample A, B, and C with the minimum acceptable standard of WHO, and NAFDAC. The laboratory test result of sample A will be used as a control to check the change in water quality for the other samples tested.

4.3.2.1 Physical Analysis of Result

This include the determination of water of colour, taste and odour, turbidity and other physical factors capable of impairing the quality of water such as total solids contained in the water.

i. Colour

Basically, colour that are found in water samples originate from impurities such as iron, manganese, dye, humus and vegetables. For all the samples analysed, the assessment was expressed as follows 'pure', 'moderately pure', and 'extremely pure'. The sample collected from water leaving the treatment works (sample A) is extremely pure, while that collected from the bitumen lined steel reservoir (sample B) and cement mortar lined concrete reservoir (sample C) are moderately pure and pure respectively.

ii. Taste and Odour

Addressing all sources of taste-and-odour problems is critical for maintaining public confidence in the drinking water supplied. From sensory analysis of all the samples, there were no recorded cases of taste and odour.

iii. p^H

The p^H of all the water samples (A, B, and C; 5.9, 5.9 and 6.1) was slightly acidic. This falls below the maximum allowable concentration established by NAFDAC and WHO which ranges between 6.5 – 8.5.

iv Turbidity

Turbidity generally refers to cloudiness caused by very small particles of silt, clay, and other substances suspended in the water. It is one of the impurities that are of public health concern. Even a slight degree of turbidity in drinking water is objectionable to most people. Turbidity also interferes with disinfection by creating a possible shield for pathogenic organisms. The turbidity of the water (5 and 4 NTU), meets the WHO and NAFDAC standards of 5 NTU. Except for a slight elevation in sample B (7 NTU).

4.3.2.2 Chemical Analysis of Result

The result of the chemical examination of all the samples tested is discussed bellow. However it should be noted that raised concentration of any chemical known to have an impact on human health may lead to long-term problem.

i. Total solid

The total solid in all the samples (403.7, 457.3, and 435.7 mg/l) meet the maximum acceptable standard NAFDAC (500 mg/l), and WHO (1000 mg/l). Total solid is a quantitative measure of the sum total of organic and inorganic solutes in water. The increase in Total solid from 403.7 to 435.7 mg/l in sample C and 457.3 mg/l in sample B can be explained in terms of sediment accumulation in the distribution system. This may be as result of leaching of additives or coatings used in the system material, leaching of original material itself, reaction of materials with chlorine or other additives as well as biotransformation of leachantes by fungi, algae, or bacterial in the system.

ii. Iron

Iron affects portability of water and is scale forming, most common form is ferrous carbonate. Iron can be held in colloidal suspension or in solution by organic matter. The iron concentration in all the samples, didn't meet the WHO recommended standard (0.05 – 0.3 mg/l). It increased from 0.42 mg/l to around 0.61 mg/l (fig. 4.1). It can be inferred that the elevation may be due to the leaching of additives or coatings used in the system material, and reaction of materials with chlorine or other direct additives.

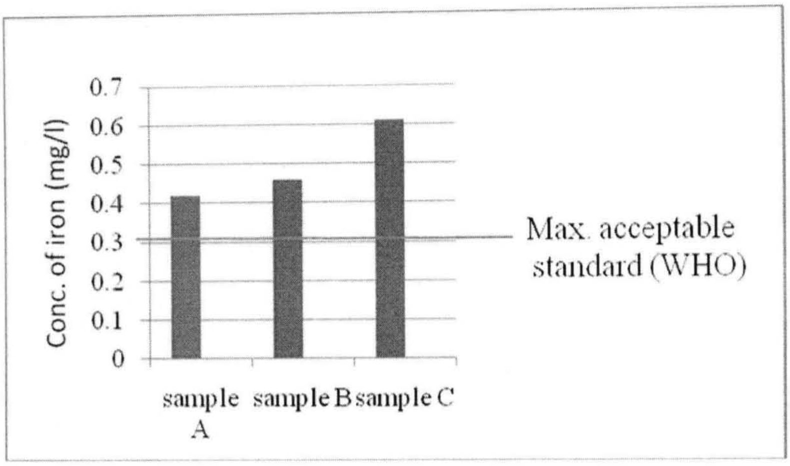

Fig. 4.1: Elevation of Iron in drinking water samples tested.

iii. Sulphate

Sulphate is a substance that occurs naturally in drinking water. The sulphate concentration in the water samples A, B, and C (260, 260 and 256 mg/l) are above the acceptable standard of 200 mg/l set by WHO and NAFDAC. A high concentration of sulphates may produce laxative effect on human system.

iv. Magnesium

The magnesium content in all samples tested (30, 35, and 30 mg/l) are within the maximum acceptable standard of 50 mg/l, prescribed by WHO. But sample B didn't meet the maximum allowable concentration (30 mg/l) set by NAFDAC. The elevation of magnesium in sample B may be attributed to the release of magnesium from the material used for lining the reservoir.

v. Chloride

Chlorides are usually present in water in the form of sodium chloride (common salt). It can be extremely corrosive as its molecular size is such that it can penetrate the protective oxide-metal interface and react with steel structures. The chloride content in the water rose from 255 mg/l to 256 mg/l and 300mg/l far above the maximum acceptable standard of 200mg/l.

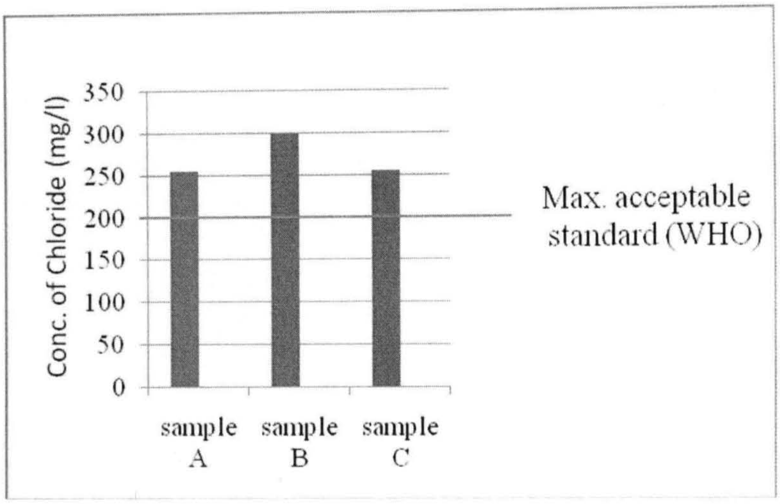

Fig. 4.2: Chloride concentration in water samples tested.

As found in the literature, unusual chemical contaminations may arise from certain conditions related to the surface application of coatings and adhesives, or from non-compliance issues e.g. addition of solvents or other chemicals not in the approved formation (Tombouliun et al 2004). This could be responsible for the high concentration of chloride in the water.

vi. Copper

Copper has an aggressive action on system materials. The copper concentration in all the samples tested (0.3, 0.3 and 0.3 mg/l) are stable and meets the maximum allowable standard of 2.0 set by WHO. This may be due to the fact that no copper-containing fixtures were employed in the water distribution system.

vii. Chlorine (free)

Chlorine is the most widely used primary disinfectant and is also often used to provide residual disinfection in the distribution system. Chlorine and Chlorine compounds by virtue of their oxidizing power first react with organic and inorganic materials present in water before any disinfection is achieved. Monitoring free chlorine at different points in the distribution system is sometimes used to check that there is not an excessive chlorine demand in distribution that may indicate other problems in the system, such as ingress of contamination. The residual chlorine in all samples tested is slightly above the recommended (WHO) standard.

vii. Manganese

The properties of Manganese are very similar in many respects to that of iron. The Manganese in the water rose from 0.1 mg/l to 0.9 mg/l. The 0.9 mg/l recorded in the bitumen lined reservoir (sample B) is beyond the acceptable concentration of 0.5 mg/l (WHO), as seen in fig. 4.3. This can be linked to the release of solvent from the coating material.

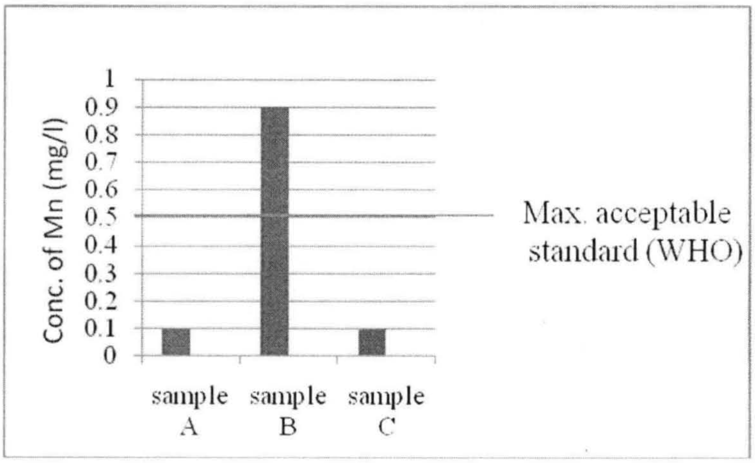

Fig. 4.3: Concentration of Manganese in all samples tested. Samples from the bitumen lined reservoir (sample B) rose drastically, high above the recommended standard.

viii Nitrate

Nitrate is present in natural drinking and waste water. It enters water supplies from the breakdown of natural vegetation, use of chemical fertilizers and from oxidation of nitrogen compound in sewage effluent and industrial waste. The presence of Nitrate in water indicates that the organic matter in the water is fully decomposed or oxidized. For all samples tested, the amount of Nitrate present in the water was within the maximum acceptable (WHO) standard of 50 mg/l.

ix. Lead

Lead concentrations in all the samples tested are far higher than the recommended guidelines (WHO and NAFDAC, 0.1 mg/l). The high level of lead in all the samples can be as a result of the mineral content and p^H of the water which can have an effect on the release of organo-lead compounds from the system materials containing lead based-based stabilizers. Lead is a toxic material and a low concentration of it can be tolerated by the human body.

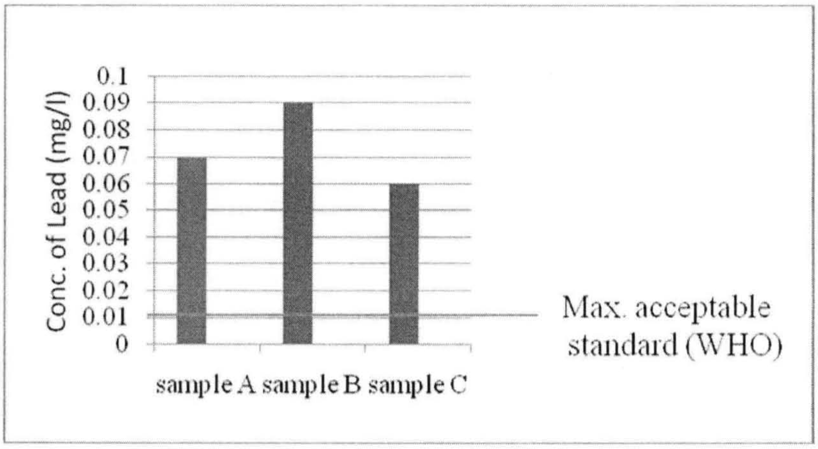

Fig. 4.4: Lead concentration in drinking water samples, high above recommended health standard.

4.3.2.3 Bacteriological Analysis of Result

The microbiological quality of water drinking-water has been implicated in the spread of important infectious and parasitic diseases such as cholera, typhoid, dysentery, giardiasis, guinea worm, and schistosomiasis. Microorganisms selected for evaluation were selected on the basis of the presence in water and likely risk to human health. Particular emphasis was given to indicator organisms that can give an early warning of faecal contamination and likely risk of disease. For all samples tested, indicator bacterial (E.coli and Coliform) was not detectable. Its absence may be due to the use of chlorine as a disinfectant.

However, bacterial multiplication takes the form of attached surface growth. This is not however so pronounced as to require the water to be regarded as unsuitable for consumption.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In this study, the nature of distribution system materials and their possible effect on water quality was investigated for system components typical of most drinking water distribution systems. The study shows that distribution network material can modify water quality during transportation to the consumers. Of particular note, is the chemical changes observed in the reservoir water in which bitumen was employed as a lining material. Elevation in most chemical parameters tested can be attributed to the release of solvents. Chemical contamination of drinking-water may have effects on health, although in general these tend to be chronic rather than acute. Acute effects may be encountered where major pollution event has occurred due to leaching of additives or coating used in the system material, leaching of original materials itself (as observed in this study), or where levels of certain chemicals are high from anthropogenic sources, such as nitrate.

The investigation on the microbial behavior of materials shows that both construction and lining materials may lead, as attested by published reports and my own observations, to the formation of microbial growths on solid surfaces. The conditions or circumstances under which such growths could develop to massive proportions were not apparent however, from the field observations. My assessment of the field observations was considerably impeded by a number of circumstances. The contamination of the water with faecal indicators such as E. coli and coliform organisms was not detectable.

5.2 Recommendations

From the findings of this study, the following are recommended.

1. The management of water utility should adopt management practices, such as optimization of the treatment process, and regulation of materials and chemicals that come into contact with drinking-water.

2. In order to prevent deterioration of drinking water quality, more studies should be carried out to indentify materials to be used for water distribution which do not encourage the growth of micro-organisms by releasing organic constituent utilizable by the organism.

3. An assessment of materials for use in contact with drinking-water on the basis of only proposed chemical and organoleptic tests is not satisfactory.

REFERENCES

Abutu, M. (2002): Water Quality Along Distribution Points (Minna Municipal as case study). unPulished, Department of Civil Engineering, Federal Unoversity of technology Minna, Niger State.

Cairncross, S. and Carruthers, I. (1980): Evaluation of Village Water Supply Planning. John Wiley and sons Inc., 126pp, New York. USA.

Chambers, K. (2004): Safe piped water; Managing microbial water quality in piped distribution system. Design and operation of distribution networks, pp. 193 -253 IWAP publishing London, UK.

Denloye, S. (2001): Consumer safty bulletin.Potable packaged water, (Denloye, S., ed) pp. 5- 10, UPI Pub., Nigeria.

Frederick, W. P (1990): Water Quality and Treatment; A handbook of community water supplies. American WaterWorks Association. pp. 332 – 431, McGraw-Hill Inc., New York.

Kevin, W. (2006): Beyond Scarcity: Power, Poverty and the Global Water Crisis. Human development report, pp. 116 -245, UNDP pub. New York.

Kooiji, D. (2003): Managing regrowth in drinking water distribution system. Heterotrophic plate counts and drinking-water safety, (Bartram, J., ed) pp. 199 – 232, Iwap pub. Co. London, Uk.

Lorch, W. (1987): Handbook of Water purification. Water quality classification, (Lorch, W., ed) pp. 84 – 93, Ellis Horword publisher, Chichester.

Modi, P. N. (2006): Water Supply Engineering. 2nd edition Rajinder Kumarjain publisher, Standard Book house Nai Sarak, pp. 231 – 441, Delhi, India.

Ross, L.C. (1987): Handbook of Water purification. Conveyance and storage of purified water, (Lorch, W., ed) pp. 599 – 639, Ellis Horword publisher, Chichester.

Schoenen, D. and Scholer, H. F. (1985): Drinking water materials: Field Observations and Methods of Investigation. Ellis Horwood publishers, 195pp, Chichester,

Sadiq, M., Muhanna, H. and Mian, A.A. (1997): Effect of distribution Network pipe material on drinking water quality. Journal of environmental science and health, 32 (2): 445-454.

Terence, J (1991): Water resources and Environmental Engineering. McGraw-hill inc., pp. 131-171, New York, USA.

Tomboulian, P. and Schweitzer, L. (2004): Materials used in drinking water distribution systems; contribution to taste-and-odor. Water Science and Technology journal, 49 (9): 219-226.

APPENDIX I

List of chemicals found by NSF to leach from system components

Pipes and liners

Cement/concrete. 2,4,6-tribromoanisole; 2,4,6-tribromophenol (Bromol); 2,4,6-trichloroanisole (Tyrene); 2,4,6-trichlorophenol; antimony; calcium carbonate (lime); calcium sulfate; chromium; diethanolamine; diethylene glycol; dioxin (TCDD); cipropylene glycol; dipropylene glycol-t-butyle ether; furan; iron oxide; magnesium oxide; melamine-sulfonate; naphthalene-sulfonate; o-phenylphenol; phenoxypropanol; tetracalcium trialuminumosulfate; tetraethyl diphosphate; triethanolamine; vanillin.

PVC/CPVC. 1,3-butadiene; antimony; calcium carbonate; calcium stearate; carbon black; chlorophenol; cyclohexanone; dibutyltin; paraffin wax; polyethylene wax; titanium dioxide; tributyltin; vinyl chloride monomer.

Polyethylene, HDPE, PEX. Acetophenone; 2,4-bis (dimethylethyl)phenol; benzene; benzothiazole; bis-(dimethylethyl)benzene; bisphenol A; BHT (methl di(t-butyl)phenol);carbon disulfide; cyclohexadienedione; cyclo-hexanone; cylopentanone; diazadiket cyclo-tetradecane; dicyclopentylone; dimethylhexanediol; di-t-butyl oxaspirodecadienedione; hydroxymethylethylphenyl ethanone; isobutylene; methanol; methyl butenal; methyl di-t-butyl hydroxyphenyl proprionate; methyl (di-t-butylhydroxy-phenyl)propionate; methylbutenol; nonylcycloprppane; phenolics; phenylenebis-ethanone; propenyl-oxymethyl oxirane; t-butanol; tetrahydrofuran; trichloroethylene.

Poyurethane coatings and liners. 1,4-butanediol; 4,4-methylenedianiline; bis(2-ethylhexyl)phthalate; bisphenol A diglycidyl ether; butyl benzyl phthalate;

diphenyl(ethyl)phosphine oxide; di-t-butyl methoxyphenol; ethylhexanol; tetramethyl piperidinone; toluene diamine.

Epoxy coatings and liners. 1,1-dichloroethene; 1-methoxy-2-propanol; 4,4-methylenedianiline; benzaldehyde; benzidine; benzyl alcohol; bisphenol A; bisphenol A diglycidyl ether; bisphenol F; butoxyethanol; diethylenetrianmine; diphenyl ether; epichlorohydrin; ethyl benzene; ethyl hexanol;isobutyl acetate; isopropoxy propanol; methylisobutyl ketone; n-butanol acetate; nonylphenol; phenol; toluene; tripropylene glycol; styrene.

Joining and sealing materials (adhesives, caulk, flux)

Diethyl phthalate; ethanolamine; lead; methacrylic acid; organotins.

Gaskets and O-rings

Nitrile-butadiene rubber. 1-phynylethanone; 2-(2-butoxyetoxy)ethanol; 2,4,5-trichlorophenol; 2-ethyl hexanol 2-phenyl-2-propanol; acrylonitrile; benzothiazole; benzothiazolethione; benzothiazolytiomorpholine; bis-(ethylbenzyl) ester; butadiene; butoxyethoxy ethanol; carbon disulfide; cyclooctadiene; dicyclohexyl urea; dimethyl carbamic chloride; dimethyl cyclohexyl urea; dimethyl dithiocarbamate propionitrile; dimethylethyl phenol; diphenyl guanidine; isocyanatocyclohexane; isothiocyanatoethane; mercapto-benzothiazole; methoxybenzene; tetramethylthiourea; tetremethylurea; tri(butoxyethyl) phosphate; tripropenyl triazinetrione.

Thread compound

Benzaldehyde; diacetone alcohol; ethoxylated bisphenol A dimethacrylate; lead; methacrylic acid; methanol; phenolics; tetrachoroethane; tetramethylene glycol dimethacrylate.

APPENDIX II

Population of Chanchaga local govt. area Minna, Niger State.

Census year	Population (thousands)	Population Density (person/square km)
1991	143,896	1934
2006	202,151	2717

Source: National population commission Minna, Niger State.

APPENDIX III

Distribution network material's questionnaire

Questionnaire no interviewer …………………

User name ………………….. Date ………………..

This questionnaire is designed to help understand the various materials used in the distribution network system of chanchaga waterworks.

Please tick the appropriate boxes

Part A

a. Rising mains

i. Pipe materials

☐ Ductile iron pipe

☐ Asbestos cement pipe

☐ Others, please specify ……………………………

ii. Lining materials for pipe

Does the pipe have any internal lining?

☐ Yes

☐ No

If No, please go to Part B

If Yes, please indicate the type of lining material;

☐ Bitumen

☐ Cement mortar

☐ Others, please specify ……………………………

Part B (reservoirs)

i. Material of construction

a. Biwater reservoir

☐ Reinforced concrete

☐ Steel

☐ Others, please specify ....

b. Shiroro reservoir

☐ Reinforced concrete

☐ Steel

☐ Others, please specify ....

ii. Internal lining materials

a. Biwater reservoir

☐ Bitumen

☐ Ceramic tiles

☐ Polyester

☐ Polyurethane

☐ Concrete mortar

☐ Epoxy resin

☐ Chlorinated rubber

☐ Others, please specify ....

b. Shiroro reservoir

☐ Bitumen

☐ Ceramic tiles

☐ Polyester

☐ Polyurethane

☐ Concrete mortar

☐ Epoxy resin

☐ Chlorinated rubber

☐ Others, please specify ....

iii. Age of reservoir

a. Biwater reservoir

- ☐ 1 – 10 years
- ☐ 10 – 20 years
- ☐ 20 - 30 years
- ☐ 30 – 40 years
- ☐ Over 40 years

b. Shiroro reservoir

- ☐ 1 – 10 years
- ☐ 10 – 20 years
- ☐ 20 - 30 years
- ☐ 30 – 40 years
- ☐ Over 40 years

iv. Time of last cleaning/washing

- ☐ 1 -5 years ago
- ☐ 5 – 10 years ago
- ☐ Others, please specify ……………………….

v. Capacity (liters)

a. Biwater reservoir

- ☐ 1 – 2 million liters
- ☐ 3 – 4 million liters
- ☐ 5 – 6 million liters
- ☐ 7 – 8 million liters
- ☐ 8 – 9 million liters
- ☐ Others, please specify …………………….

b. Shiroro reservoir

- ☐ 1 – 2 million liters
- ☐ 3 – 4 million liters
- ☐ 5 – 6 million liters
- ☐ 7 – 8 million liters
- ☐ 8 – 9 million liters
- ☐ Others, please specify ....

Thank you for helping.